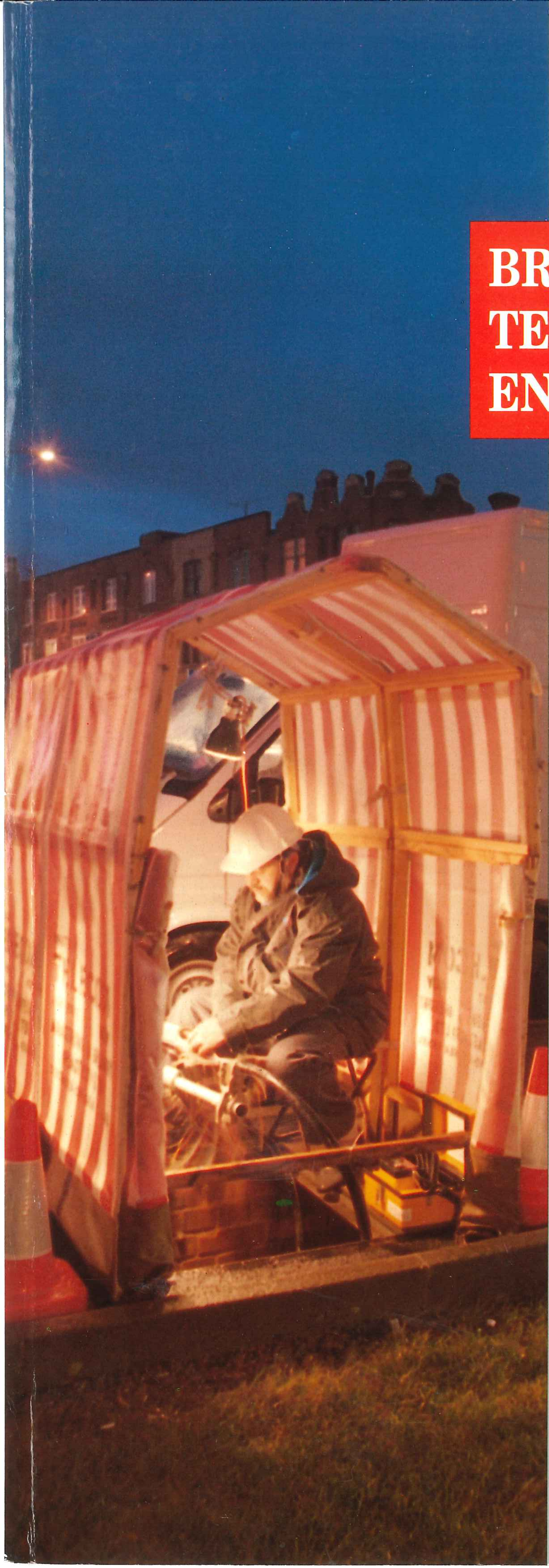

VOLUME 10 PART 4 JANUARY 1992

BRITISH TELECOMMUNICATIONS ENGINEERING

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BRITISH TELECOMMUNICATIONS ENGINEERING

GUEST EDITORIAL by John Ziemniak

Historically, the business of telecommunications service provision has been one typified by customers having a need (basic telephony in many cases); the role of the PTTs, in particular the engineering functions, has been to provide this service in faster time-scales, with higher quality and at lower cost allowing for inflation.

Significant strides have been made in all of these key objectives, but the market never stands still and what is acceptable today is not so tommorrow. I believe we are now moving into a different era: competition is growing stronger and new entrants are coming into the market. Growth in BT's revenues will depend on the company's ability to 'sell' rather than simply because customers pick up the telephone more often.

Selling is more difficult because not only are we competing with others, but we also have to create within customers' minds the desire to 'buy' our new products and services. This presents a significant challenge to the engineering fraternity in that the architectures that we propose and implement need to be more flexible, cost effective at very low volumes and more feature rich than the competition. The products and services as seen by BT's customers also have to be very easy to use and customers will increasingly desire their own control of these new services.

Success can only be achieved if we not only deliver on our old targets of speed of provision, better quality and lower costs, but also have within the company a strong engineering fraternity that thinks in customer terms and 'makes it happen' in these new areas. We should welcome this challenge.

JOHN ZIEMNIAK
Director, Policy, Planning and Performance
BT Worldwide Networks

The Global Challenge: BT People Overseas

J. C. STOCKBRIDGE†

This article outlines BT's operations and experience overseas and sets a context for the further development of Group strategy. It concentrates on the activities in the Middle and Far East, and Africa where the company's long experience of consultancy, training and supply contracts extends over many years. Looking forward, the prime focus is Europe, North America, Japan and other markets with a geographic concentration of targeted multinational customers. This article is based on a lecture to the IBTE London Centre which sought to convey the flavour of BT's overseas activities and the challenges which arise. The context is the mission to provide a quality service to a new set of overseas clients. Service is essentially about people and their interrelationships, supported by the technology, networks and systems which make up BT's organisational capability. Complex though these are, they are overshadowed by the challenge of providing excellent services to customers the world over, in different climates, cultures, languages and customer requirements.

INTRODUCTION

The business of providing services to customers worldwide can often be challenging, is frequently rewarding and might even occasionally be frustrating, but it is essentially about people.

BT experience in operations overseas has given the company thorough knowledge of how to overcome the obstacles of language, culture, varying climates and what each customer wants.

Activities in the Middle East, the Far East and Africa stretch back over many years while the main focus for the future includes Europe, North America, Japan and markets where transnational customers are concentrated.

† Regional Director, Asia Pacific, BT Business Communications

BT's mission is to provide a high-quality service to new clients overseas. That service depends entirely on two major factors, people and high technology.

The economically emerging Asia-Pacific region is one of three areas targeted outside the UK along with Europe and America. BT already has more than a decade of experience in Asia-Pacific, mainly in consultancy work and equipment sales. In Europe, BT links stretch back much further: the first telephone line from London to Paris opened a century ago in 1891.

Whichever continent BT is looking at, the Group's aim is to provide world-class telecommunications services which will fulfil customers' needs, sustain earnings growth for BT shareholders and make a worthwhile contribution to the communities in which business is conducted.

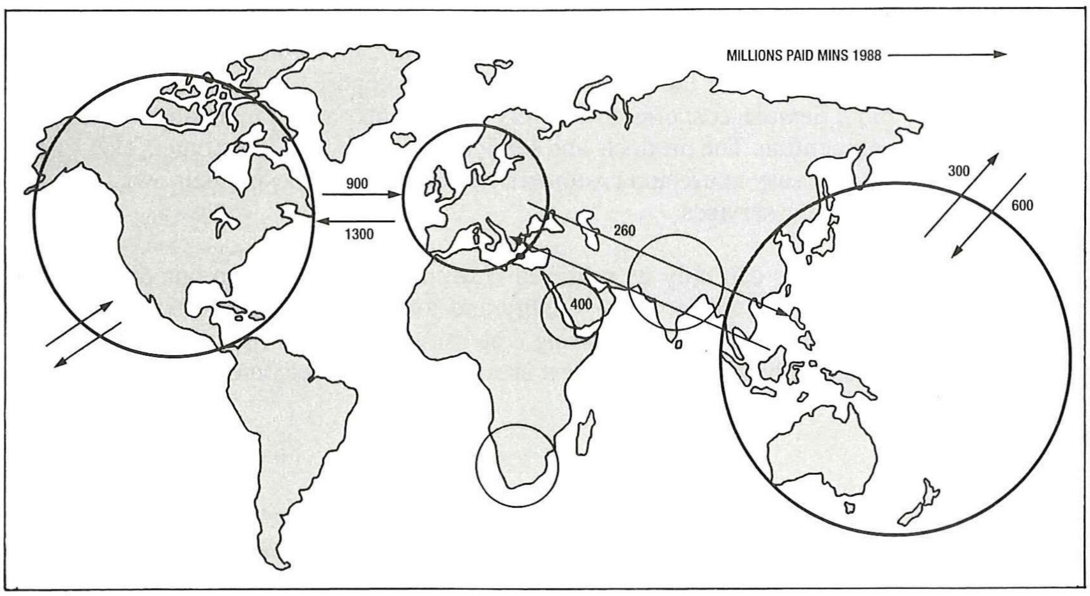
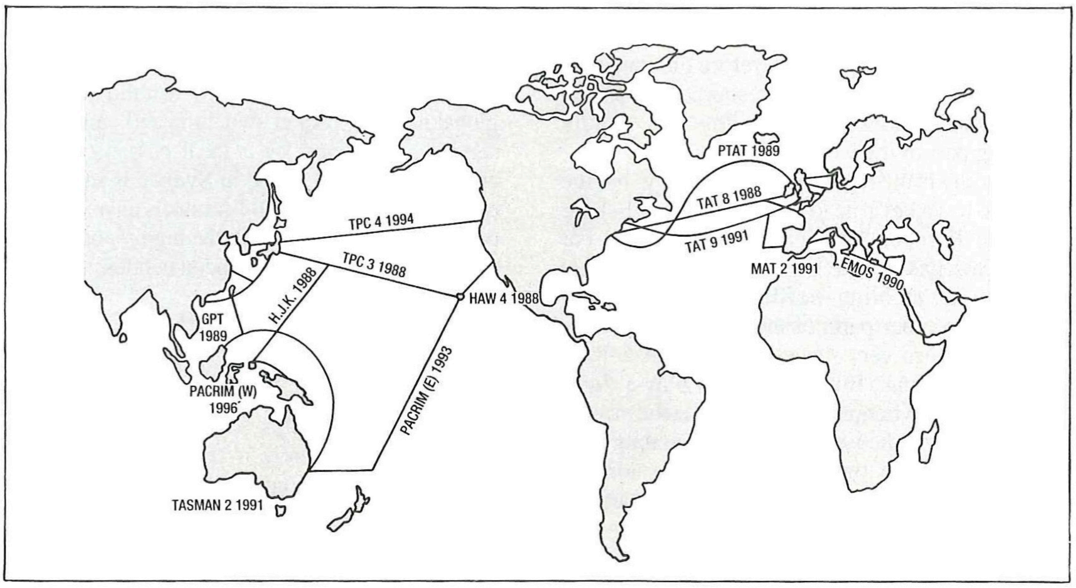


Figure 1
Inter-regional traffic flows

Figure 2
Global digital optical-fibre network



BT'S WORLDWIDE STRATEGY

BT's strategy in the world telecommunications marketplace is based on three basic principles:

- It is fundamental that BT must continue to be the leading supplier in its home (UK) market.
- Overseas, where BT does not have the immediate advantage of established reputation, the company must offer a range of competitive products, systems and services which can be sold in those markets.
- BT must also provide access to, or control of, its networks from all parts of the world in order to offer a complete global customer service.

To do this, BT must have a network of people, agencies and facilities providing service to customers worldwide. Without the right people, that is an impossible task.

A GOLDEN GLOBAL OPPORTUNITY

A basic law of telecommunications, illustrated by Figure 1, unsurprisingly indicates that most traffic flows between the centres of business and population growth. The importance of the UK in these flows is further illustrated by Figure 2, where the pivotal position of UK relative to the US, Europe and Africa is clearly identified. This axis is also linked via the Middle East into Singapore and Malaysia, through to Australia, and, of course, to Japan. The circuit is completed by the path leading back to North America.

That network of communications around the world reflects a pattern identical to the principal routes of airlines and ship operators, all of which have similar characteristics of global trading. It is around that network, therefore, that BT is now focusing its energies to develop a high level of customer service.

The implication of this is that BT is less interested than may have been the case two or three years ago in participating in national infrastructure projects in the less-developed world.

A major consequence of the strategy BT has been developing over the past year is this primary focus on the main global lines of communication and transport.

The digital optical-fibre systems that already exist and are expanding make bandwidth, a previously scarce resource with older technology, cheaper and more plentiful.

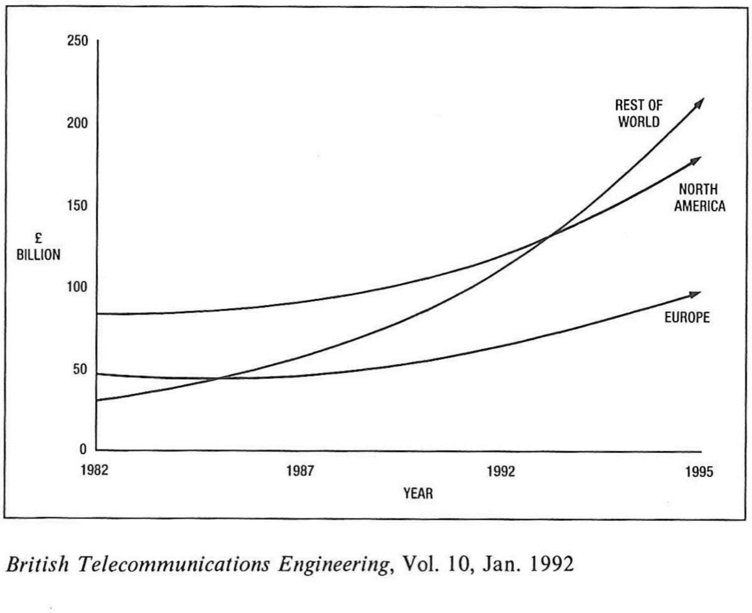
Falling costs and deregulation are encouraging many new companies to emerge and new cables may not necessarily be owned by the traditional carriers. Instead, they are being promoted by private investors who aim to maximise the amount of traffic by selling aggressively to fill their cables to capacity.

These are just some of the technological and competitive pressures being exerted now that the cost per unit of bandwidth is coming down rapidly and they present BT with both threat and a golden opportunity.

ASIA/PACIFIC: THE WAY AHEAD

The emerging market trends, depicted in Figure 3, make it clear that, five years hence,

Figure 3
Market trends in telecommunications equipment and services



Asia/Pacific countries will be spending more on telecommunications products and services than America and Europe. It is therefore obvious why BT is devoting considerable resources on getting fully established in this exciting and rapidly growing part of the world.

Not only is the region itself expanding, but the UK also has a key role to play in transit switching between Europe, America, Africa and the Far East. This has, in the past, given BT an ideal opportunity to bring traffic into London and switch it to other parts of the world: an activity which has been very successful for British Telecom International. But BT does not play a significant part in switching the growing traffic around the Pacific and the issue here is of deciding how best to approach this market. BT has already invested in many of these cables as either partners or lessees.

For some years, satellites have dominated the phenomenal growth in capacity, but optical fibres are now re-establishing the importance of terrestrial routes. The main satellite facilities used to be overshadowed by INTELSAT and INMARSAT, but the choice is widening as many other satellites are launched by individual countries, such as various Middle East nations, India and Australia. In these places, operators, either alone or in conjunction with partners, are putting up satellites for local use and private enterprise such as those now used for direct broadcasting in Europe.

But satellites for basic voice telephone services, which account for about 90% of BT business, have distinct disadvantages from the customers' point of view. As far as BT is concerned, however, satellites will, for the foreseeable future, have a specialised role as a supplement to basic capacity planning and, for that reason, BT is involved in many of these projects. Against this background, there is a picture of BT people putting into practice this strategy.

Australia—At The Competitive Edge

BT started in Australia in 1984, has a registered company there and trades in products, customer services and investments.

A small research and development centre was established at Parramatta in 1989 to meet Australia Government approval requirements for operating there. BT had to demonstrate value added to the local infrastructure, and this centre customises products for the Australian market. Activities at the centre focus mainly on customer premises equipment, including product development and the coordination and management of local manufacture. The centre has a group of experienced systems engineers capable of both hardware and software development. The laboratory is equipped with modern tools and equipment enabling in-house computer-aided design and PCB board layout, circuit simulation and other facilities.

Other activities include the provision of private networking facilities and the supply of financial trading systems, the latter being the generic identity of the BT City Business Products touchscreen dealerboard systems.

Tymnet is also present in Australia and offers global network packet switching and value-added services, supported by a local customer service company. The BT office in Sydney is in an ideal central location, where BT products have given the company a leading edge in the highly competitive market to supply main financial centres.

Japan—A Growing Market

BT's presence in Japan began in 1985 and is involved in sales, account management and correspondent relationships. One interesting insight into BT business there is the fact that the company's high-technology modems and other equipment can be sold into Japanese markets, where BT's reputation for research and development is important.

BT also has very important collaborative arrangements with NTT, which is Japan's national operator and the largest telephone company in the world. It employs half a million people, and has three times as many customers as BT. Through direct investments in Japan and the acquisition of Tymnet, BT has already established an important presence and is positioned to take advantage of a very large growing market.

Always willing to adapt to local customer requirements, BT offers a version of its financial trading system with Japanese (Kanji) characters, which is distributed and maintained within Japan by Mitsui.

Hong Kong—At The Financial Forefront

BT's business in Hong Kong started five years ago with financial trading systems. One example of its use there is in a major bank where it forms part of a global account, the customer being spread widely throughout the world although not, historically, of a major size in the UK. This means a very diversified type of customer to look after as far as account

Jerry Stockbridge (author) with other BT people at the official launch of BT in Singapore in May 1991 (left to right: Jane Foo, Jerry Stockbridge, John Poston and Michael Thio)

management is concerned and one where BT has had to start virtually from scratch.

BT also supports local community projects, an important BT value the company is always ready to put into practice.

Singapore—Also Providing Marine Services

In Singapore, many different activities are covered. A local BT company provides a maintenance service for electronic marine and communications equipment and provides a sales outlet for the BT cableship fleet, which is one of the largest and most cost-effective in the world. Given the scale of planned penetration of cables in the Pacific, this provides the company with an excellent opportunity to win business by laying and repairing undersea systems.

Financial trading systems are also demonstrated at the local BT office which has also, more recently, become the base for the company's regional sales and account management force.

Thailand—Collaboration and Assistance

In Thailand, the government has decided to develop a modern network by inviting foreign partners to work with Thai companies to build and operate the networks needed for growth. This is being undertaken in a spirit of collaboration with the public network operator rather than in the competitive sense.

BT is involved in a consultancy programme to support this initiative, demonstrating how BT's experience of privatisation and liberalisation gives it an edge, via the consultancy route, in markets now following the same path. Few established operators have had to make such rapid adjustments to the commercial environment as BT, and the company is looked to as a source of advice and guidance by other operators going through the same processes of change.

The Middle East—A Key Market

In Saudi Arabia, BT-al Saudia is a joint-venture company which provides customer support services and network selling capability. Established in 1989, it already has important data networking customers and is well placed to win key multinational accounts as business returns to normal after the Gulf War.

BT and a Saudi partner have just completed a three-year operations-and-maintenance contract for the Saudi telex and public data network. BT's experience and standing in general in the Arabian Gulf means it is ideally positioned in a difficult but key market for those industry sectors which are important to the company; that is, energy, finance and transportation.

BREAKING DOWN THE BARRIERS

Building relationships with customers, partners, policy makers and regulators has allowed BT to enter many new markets which are culturally and structurally quite different to those in the UK, where corporate and operational experience and standing has been developed over several decades. But the company has succeeded with entry strategies in all the key markets and now employs several thousand people who, collectively, have learned how to break through the barriers, develop relationships and get business underway.

The success BT has had in penetrating these new markets is extremely encouraging and reinforces the company's vision to become the most successful worldwide telecommunications group.

THE TRANSNATIONAL CUSTOMER

The telecommunications market is now global and BT is operating on that scale. The activities described above play a crucial role in expanding BT's operations worldwide and they are a crucial component in what is becoming BT's increasingly seamless global network and sales operation.

In this broader context, these activities also play a vital role in BT's new thrust towards meeting the needs of customers more precisely. This recognises that many large companies and corporations have become transnational in their operation and that the increasing international dimension of commerce and trade will continue to lead to unprecedented growth in demand for international telecommunications.

Many of these customers require complex private international communications networks in order to conduct their business, and telephone service providers can provide these either as a physical or, increasingly, as a 'virtual' network. The trend away from leasing exclusive circuits to facilities using the public network as a platform has been noted and is a major opportunity for BT to exploit its international strengths.

More and more customers also want to free themselves of managing an increasingly complex combination of hardware and software from many different suppliers. They want to concentrate on their 'core business' and leave telecommunications problems to others, but without losing the feelings of control and security which they have acquired during years of 'doing their own thing'. They are, therefore, open to considerations of placing their networks in the hands of third parties (outsourcing), but only if those parties can demonstrate a high degree of performance and reliability linked to real savings in operational costs.

BT's sophisticated Concert™ network and facilities management offering is uniquely placed to satisfy these needs because it can manage multivendor networks on a national or international basis.

One-stop shopping is the next logical development of this rationale. In the field of global private voice and data networks, BT's new company

Syncordia breaks new ground by providing transnational companies with a single organisation to manage their complex international communications systems.

The Global Network Service (GNS) portfolio offers transnationals managed networking services and international value-added services on a worldwide scale. By integrating domestic Tymnet and International Packet SwitchStream (IPSS) networks in the USA and the UK, as well as cross-border services available through its IPSS and the Tymnet global network, BT is able to offer enhanced data connections to more than 100 countries, including complete end-to-end service to 20 countries.

THINK GLOBALLY, ACT LOCALLY

BT is also working closely with other telecommunications operators around the world to simplify the setting up and running of customers' international private networks. It is all part of meeting the challenge of *thinking globally, acting locally*.

This challenge is being faced as BT emerges as a major player operating on a global scale—all a far cry from the buff forms, green vans, black telephones and red kiosks which greeted 'subscribers' to the GPO telephone service.

What has not changed is the commitment and dedication of BT people, the single most important factor in the organisation's quest to become the most successful worldwide telecommunications company.

Biography

Jerry Stockbridge was educated at Wimbledon College and joined the then British Post Office as an engineering trainee. He graduated in Electrical Engineering at Imperial College, London, and, spent two years in charge of cable planning in South West London. He subsequently gained a Masters Degree at Imperial College in Operational Research and spent four years working in the Post Office Personnel Department. In 1974, he transferred to the London Telecommunications Region, spending two years as the Deputy General Manager in the City of London, and two years as Personal Assistant to the then Chairman of the Post Office, Sir William Barlow. He was appointed General Manager of BT London West in 1979, a post he held for four years before being appointed Deputy Regional Director in charge of Service for BT London. From 1984, at UK Communications Headquarters, he was Director of Operations in charge of Operator Services Management Audit, and Operational Computer Systems, and Director, Residential Network Services, with responsibility for residential telephony, payphones, premium rate services and introduction of the computerisation of Directory Enquiries. In October 1988, he was appointed Director, Telecommunications Overseas Division, responsible for equipment sales, consultancy, network projects, and the supply of telecommunications manpower services. In April 1991, he was appointed Director of Asia Pacific region of BT Business Communications, responsible for territory operations in the Middle and Far East, and Africa.

The Haves and Have Nots of the Information Age

R. K. SNELLING†

Within the next ten years, telecommunication operating companies will have built an infrastructure capable of providing information age services. This infrastructure will be a key element in the economic growth and viability of a community or a country. Those countries with a progressive regulatory regime will benefit from the rapid development of this infrastructure, those without will lag behind. This article explores the impact of the regulatory, technological and market aspects of the information age network.

INTRODUCTION

Ten years from now, many telephone operating companies in the United States and around the world will have built a telecommunications infrastructure capable of providing information age services. The thesis of this article is that this infrastructure is a key enabler of economic development and viability for a community or a country, as well as an enabler of a high quality of life for all citizens. The communities and countries with the best and most progressive regulatory and/or competitive environment will develop the infrastructure more rapidly and effectively. Thus, they will become the 'have' nations. Conversely, without a progressive regulatory and competitive environment, other countries will lag in the deployment of their telecommunications infrastructure (that is, network of networks) and will become the 'have nots'.

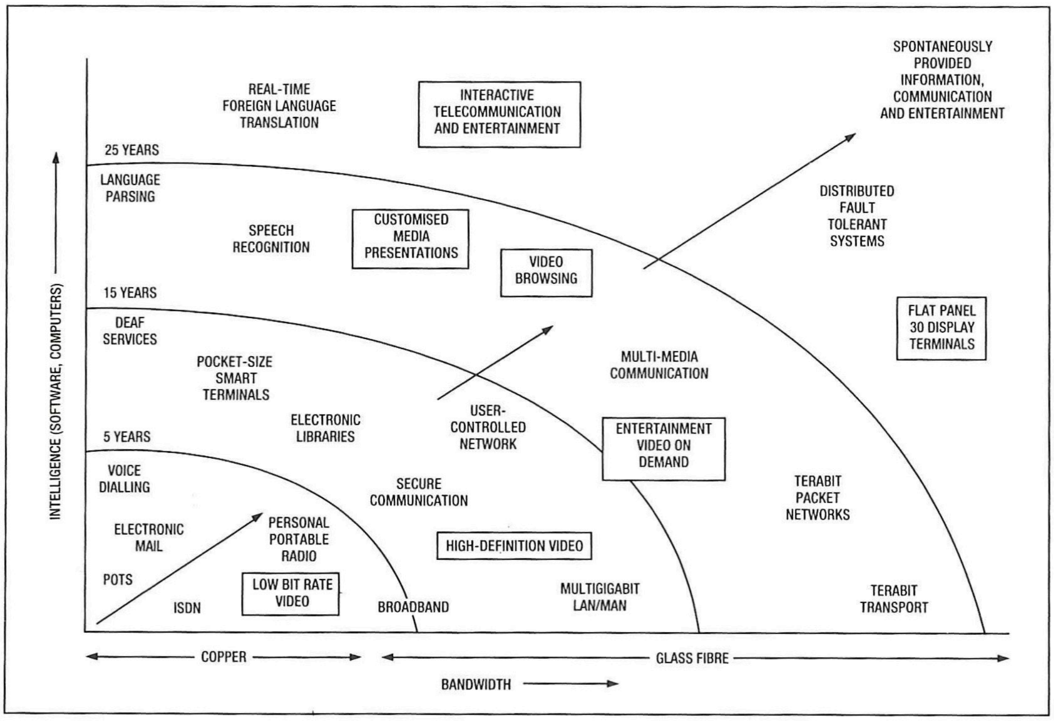
This article explores the implications of this thesis and the impact of the regulatory, technological and market aspects of the information age network. As a reference and starting point, it is appropriate to begin with the evolution of the network as exemplified by BellSouth Telecommunications, Inc.

NETWORK EVOLUTION

The network evolution that is taking place includes the transition from analogue to digital, copper to fibre, and baseband to multiplex. Figure 1 reflects this programme with 1980 as the time origin. The horizontal axis reflects what happens as you move from a copper-based network to fibre; that is, unlimited bandwidth. The vertical axis shows what happens when you move from passive switches to intelligence by using

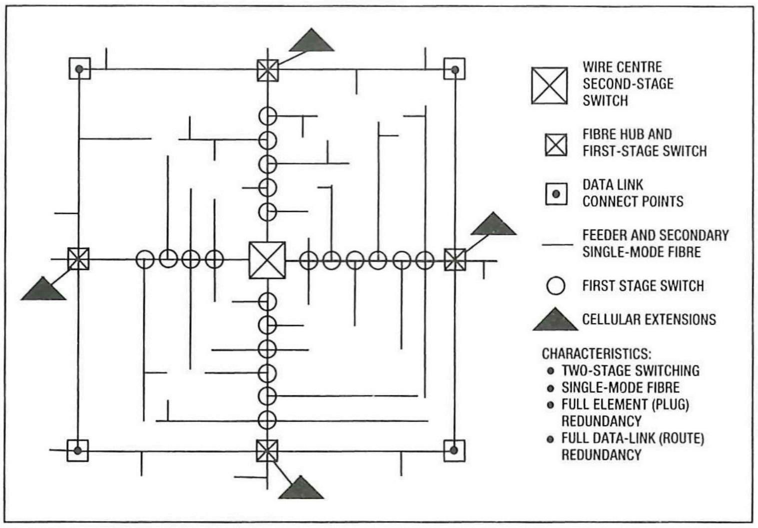
† Executive Vice President – Network Operations, BellSouth Telecommunications Inc.

Figure 1
Progress towards the information age



software and computers. Overall, what is depicted is the resultant customer services; that is, an explosion of dynamic services—voice, data, image and video—forecast by years. So far, this forecast looks very accurate.

Figure 2 is an illustration of a 'network of networks'. It also depicts how that network would be constructed. The design includes the concept of multi-stage switching, broadband synchronous envelope (SONET), and customer-controlled voice and data in a self-healing wire (fibre) centre. An overlay fibre network is built on top of the copper-based network, with the switch progressing through three modules; that is, voice, fast packet, then image or video under the control of asynchronous transfer mode (ATM). Architecturally, this network is fully capable of interfacing with other networks, such as personal communication networks (PCN), or personal communication systems (PCS), wireless cable-TV (CATV) or alternative access providers. Most importantly, it provides very efficiently for a full range of services for the customer.



The broadband synchronous envelope customer-controlled voice, data and image self-healing wire centre

Figure 2—Network of networks

Network Requirements

To add credibility to this conceptual design, the network that BellSouth is developing is now described. The network is:

- self-healing;
- integrated (that is, integrated services digital network (ISDN)—narrowband and broadband based);
- intelligent; and
- 'automatic', so that customers can gain access to the network under their control without interfacing with the carrier at all for dial tone, bandwidth, features and platforms.

It must also be:

- 'telco programmable'; and
- 'customer controlled'

so that the telephone company can, through the use of feature nodes, quickly provide customised services or customers can provide such services or changes for themselves (advanced intelligent network 2).

To build this infrastructure, fibre optics are needed as an enabler. Figure 3 illustrates the amount of fibre-miles shipped in a given year in BellSouth. As the deployment of fibre is increased, there is a corresponding decrease in miles of copper shipped. A steady increase of

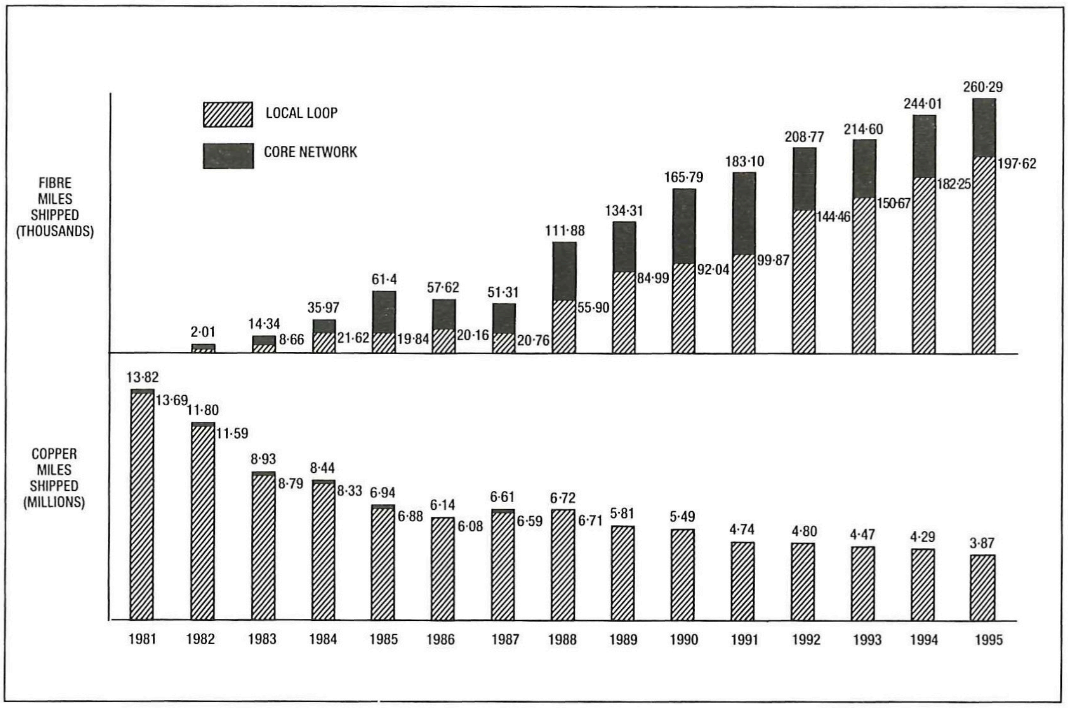


Figure 3 BellSouth Telecommunications facility accomplishments

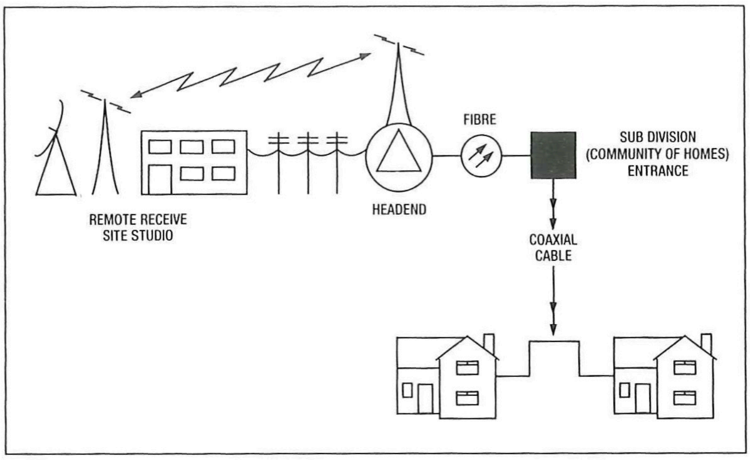


Figure 4
Fibre-coaxial hybrid CATV

fibre-miles over the next few years is predicted and this increase is expected to be primarily in the loop, as opposed to the trunk, network. This means that, today, BellSouth is putting in fibre at the rate of 95 miles per hour (or approximately 60 km per hour). In terms of capability, using SONET as the standard, it means that the infrastructure that took 115 years to construct in the previous copper technology is totally reproduced every 3·3 days. This is a powerful network indeed, capable of far more than simply voice, although it is economic for voice alone.

CATV has now joined the telecommunications industry in the deployment of fibre. Figure 4 illustrates the dominant architecture that the National Association of CATV companies is declaring as its preferred architecture. Fibre is placed in the backbone feeder routes, with coaxial cable in the local distribution network. There is further indication that the CATV industry proposes to use wireless technology—in addition to one-way video—at the subdivision entrance to the living units for voice and video services. Both CATV and the telephone industry are moving towards the same market with very similar architectures. In fact, it seems reasonable that both industries will use each other's architecture when the opportunity presents itself. Time-division multiple access (TDMA) and code-division multiple access (CDMA) are the enabling wireless technologies.

Figure 5 depicts the current fibre-to-the-curb architecture for telecommunications. The various components are reflected, showing similar architectures with a slight deployment difference at the end, but the customer and the technology are the same.

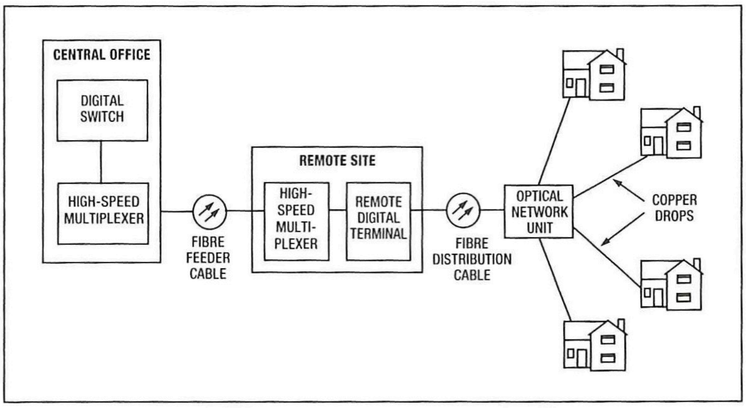


Figure 5
Fibre to the curb

Switching Requirements

Another element of the telecommunications infrastructure is switching. BellSouth's switching accomplishments include the complete conversion to all-electronic in 1990, with presently better than 50% digital, and projections for 80% digital by 1995. This lays the foundation for the next generation switch modules as follows:

(*a*) *narrowband circuit switch* characterised by switches that are already deployed today and providing the foundation for baseband;

(*b*) *narrowband packet switch* characterised by Northern Telecom's DPN and other systems;

(*c*) *broadband circuit switch* characterised by CCITT Group XVII, which accommodates switched video transport including advanced definition; and

(*d*) *fast packet module* performs the steering functions for the other three modules. It also performs the 'mixing and de-mixing' functions so that the bits moving into the switch go to the appropriate switch module for proper treatment using ATM or bandwidth on demand.

The deployment of common-channel Signalling System No. 7 is critical to the evolving network. BellSouth projects that by the year-end 1991, 76% of its access lines will have common-channel signalling as their foundation which provides for custom local area signalling services (CLASS), see Table 1. The market has been extremely receptive to these CLASS services, which in BellSouth are known as *Touchstar*™.

BellSouth is also committed to the deployment of ISDN, and projections are that 121 switches will be equipped with ISDN at the end of 1991. This number doubles almost every year through the early-1990s.

Earlier, the goal of making the network 'automatic' was mentioned. The automatic network is tied together by systems and databases as depicted in Figure 6. This illustrates that BellSouth takes the customer request and enables the switch

Table 1
BellSouth Telecommunications Common-Channel Signalling

	1989	1990	1991	1992	1993	1994
Percentage access lines equipped with common-channel signalling	46·7	57·7	75·7	87·6	92·8	96·8
Number of common-channel signalling equipped switches	333	599	833	1186	1402	1538

to provide dial tone and other types of service for business and residence. In a portion of the service area, that is, in the four eastern states of the BellSouth region, dial tone can be provided untouched by human hands 46% of the time.

A new service called *Quick*^{sm}*Service* is offered and requires no visit in order to connect new service. When premises are vacated, there is no physical disconnection at the central office or at the premises. Dial tone is present always, but contact can be made only with the telephone business office (and the emergency services). The new customer simply dials the telephone business office to arrange for billing and features. Full service can be provided within a few hours without the need to dispatch a technician. This is the precursor service for the automatic network.

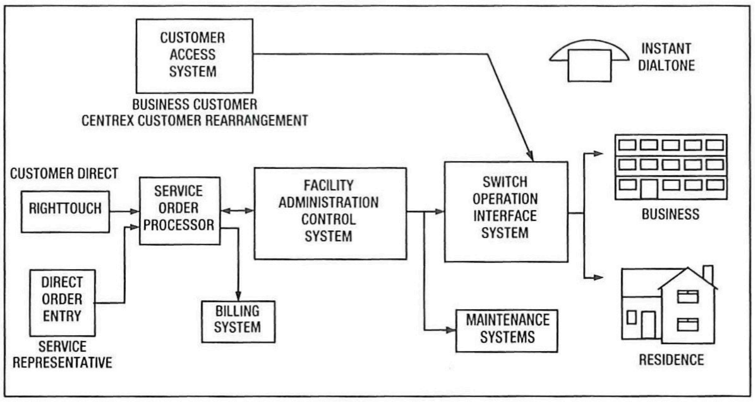


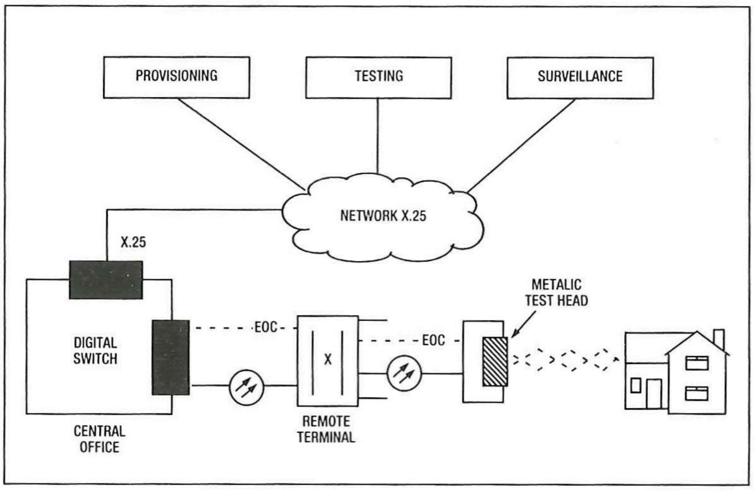
Figure 6—Service order provisioning in an automatic network environment

Network Management

As fibre continues to be deployed economically further into the network, fibre-in-the-loop (FITL) operation-support systems for provisioning, testing and surveillance are also being deployed very rapidly in the United States and, indeed, worldwide (Figure 7). The Raynet system, called *RIDES*, is becoming popular in the United States, both for Raynet as well as other fibre-based systems. BellSouth presently has an outstanding bid request for fibre-to-the-curb systems. It is expected that several manufacturers/suppliers will meet the bid price. If this happens, BellSouth will contract one or more suppliers to equip up to 100 000 living units. This will enable BellSouth to be 'off and running' with fibre-to-the-curb applications and will thus have broken the learning curve dilemma.

One of the most advantageous applications of fibre technology is in the evolution of a self-healing network. In BellSouth, there are many examples. One is the Atlanta Metro Fibre network, which by 1995 will be primarily digital, with a self-healing trunking network (see Figure 8). This is coupled with self-healing capabilities planned for the loop feeder routes so that approximately 35% of these routes will be self-healing in the same timeframe.

This means that if there is a break in a node, or simply a cut by a road digger, the route works; that is, transmission continues in the opposite direction round the loop. During the Gulf war, a situation was experienced when a 12-fibre cable serving Fort McPherson was cut. Six wire centres serving 155 000 lines were potentially affected. The route healed itself as service was switched to an alternative route in less than 50 ms, with no service interruption to customers. This **is** the network quality of the 1990s from the customers' perspective—a reliable and survivable network.



EOC: Embedded operations channel

Figure 7—Fibre-in-the-loop operations support

Customer Interface

The final piece of the architecture is the home network controller (which can also be adapted as an office network controller). The home network

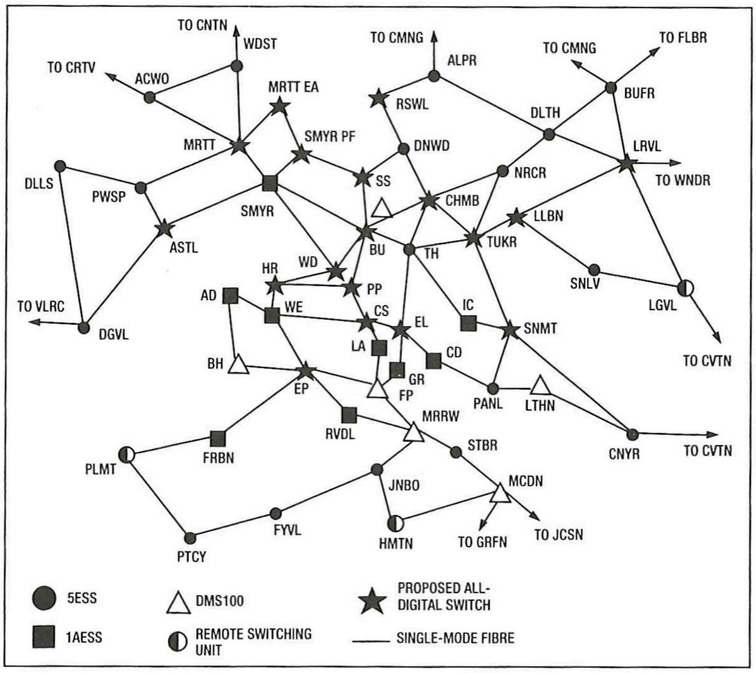


Figure 8—Atlanta Metro Fibre network (1995)

Table 2
Facilities of the Information Age Home

Input/Output	
Home computer	Personal Smart house
Audio	High-quality stereo Intercom
Video	High definition Flat screens Interface to standards
Master antenna and wiring systems	
Systems	Home security Life support Energy management Videotex Meter reading
Financing	Mortgage—new Contract or purchase—existing
Functions	
Multiple	Monitor and Control Input/output
Characteristics	Synergistic Robust Inexpensive
Telco	System integration role

controller becomes the platform to which the consumer electronics of the living unit are shared; the multiplex over the fibre is terminated, and the customer-specific central office functions are distributed—all integrated for communications. Then, PCS can also be integrated so as to extend the network from the home. Table 2 suggests some of the typical facilities of the information age home.

COOPERATION AND COMPETITION

In order to facilitate the advancement of technology and the network architecture described thus far, it is firmly believed that cooperation **and** competition are necessary requirements. It is also the view that cooperation and competition can coexist and to that end, the appropriate governmental and/or regulatory bodies should seek unique and creative ways to foster an environment that supports both—dependent, of course, on business needs.

Given this dual scenario, there is a fear that chaos would result from an unconstrained competitive level of activity. Certainly, there are examples of that around the world today. To prevent such chaos, however, the parties or players should be limited in number by the regulatory bodies; that is, limited to two, three parties etc. Perhaps a good start would be the creation of a duopoly for local service areas. But whatever the parameters or limitations might be, one key element is that the government agencies must ensure a 'level playing field' between all the contending parties. This is true not just for the parties directly involved, but also for all those who wish to interface with them.

Provision of Competition

Around the world, there have been a number of efforts to provide for competition. The United States may have been one of the first, but its use as a model is limited and there are far better examples. Probably the best to serve as a model for the rest of world is Australia—far away and 'down under'. Australia seems to have learned from the mistakes and experiences of others. It is building on the 'shoulders' of those who have strived long and hard to move away from a controlled monopoly environment to one of more competition.

Australia is presently providing for a second carrier opportunity. In so doing, it will continue to provide telecommunications under national jurisdiction. Apparently, the government is concerned about too much telecommunications deregulation, and as a result, has decided that they must regulate to create a duopoly. They are prepared to regulate to prevent the dominant carrier from 'destroying' or adversely affecting the competitor. A further part of their strategy is that the second carrier should have less regulatory control. In addition, the government of Australia also plans to give total access to the primary carrier's local loops and customers. This principle is, of course, completely contrary to the United States approach going back to 1982, prior to divestiture, when it was decided that companies could separate toll and customer premises equipment from the rest of the network. (Unfortunately, electrons and photons do not know if they are in the regulated or unregulated mode!) This particular principle has not served the United States well nor others where it has been applied.

Another factor in the Australia case is that there is no limit on what the second carrier can provide with respect to both facilities and service. The government will allow interconnection with the first carrier as needs dictate. At the same time, they will allow the second carrier the use of physical facilities (conduit runs, streets and rights of way, etc.).

Competing Industries

This raises the question of why have opportunities like this not been propagated in other parts of the world? Part of the problem is a fundamental one; that is, businesses compete for profits and have different stakeholders. The industries involving

computers, CATV, broadcasting, telecommunications, and consumer electronics all use common technology. In many cases, the chips are the same and serve common purposes; however, the industries have different owners and shareholders (that is, stakeholders). Unfortunately, there is a tremendous contention worldwide, which is, in fact, deferring the information age. Responsible governmental bodies must foster a higher level of understanding so that these interested parties can move to the market with a 'level playing field'. In the United States, this means that the current struggle between the CATV industry and the telecommunications industry (that is, the 'telcos') could be mitigated significantly if there were opportunities for both parties to compete in each other's markets. This should be done with appropriate constraint and regulatory oversight sufficient to prevent abuse by either industry or the emerging alternate access providers.

The consumer electronics industry is now included in the picture because, up to this point, it has not been a central player in the development of the integrated technologies. Consequently, the standalone consumer electronics approach has basically provided a significant amount of inefficiencies in the delivery of products and systems to the business and residential markets. Examples can be found in any moderately priced home where the duplication of consumer electronics is rampant. A much more orderly and integrated approach could improve the consumer acceptance of the information age. In addition, the cost to the consumer would be significantly reduced.

The broadcasting industry, along with the CATV industry, is caught in its own struggle in the United States relative to who pays for the signals across the air. Indeed, this is a global struggle taking place in Europe, Japan, Australia, as well as North America.

The bottom-line on this whole subject of competing and merging industries is that there are five contending parties with common technologies all moving to the same market; that is, information services. The governmental and regulatory bodies must understand the forces involved and ensure that each party's needs for delivering services to the customer are recognised.

THE CHALLENGE

Given the telecommunications infrastructure described, a fundamental question must be asked: why should there be both cooperation AND competition? The answer is that with so many services coming into the network, competition will ensure the most services at the best price. There is room for alternative access providers and there is also room for CATV entry into the market. The market is growing rapidly, so let the market determine the final outcome. This means that the telecommunications industry must open up their cherished voice market to competition. And the entertainment industry must be open as well from a CATV standpoint. There may well be cooperation between the contending parties, but only as business needs dictate. All would be on a level playing field and under non-abusive regulatory oversight.

If, in fact, these issues are not addressed to allow for both cooperation and competition, there will be locations (states, regions or nations) in the provision of information services where it will be possible to differentiate between the 'haves' and 'have nots'. The 'haves' will:

- leap-frog technologically
- develop economically

and the 'have nots' will:

- fall behind
- exhibit growing political and social discontent.

Currently, the 'haves' would include Australia and portions of Europe where governmental regulation is supportive. Germany would be classified as a 'have' nation, as it moves ahead both East and West to build a telecommunications network. The United States could well become a 'have not' nation, primarily due to the disarray precipitated by the current regulatory environment.

Characteristics of the 'have' nations or regions would include:

- all digital broadband ISDN;
- all fibre;
- integration of telecommunications, computing, broadcasting, consumer electronics; and
- fully developed alternate sources of technology; for example, wireless, landline, broadcast and interactive.

With a strong telecommunications infrastructure, the 'have' nations or regions are also positioned to develop superior systems for education, health care, finance, government, entertainment, and virtually all areas of business and/or private life.

The reality of the vision is that if consumers are not provided with the most modern communications network economically feasible, they will be denied the communications capability that they may need to fulfil their economic and personal needs in the future. Indeed, those industrial, governmental and geographic areas that fail to keep pace with this technology will become the 'have nots' of the information age, while those entities who lead will improve the quality of life of the consumer/customer, attract business, and achieve high levels of share owner value.

The real challenge at this point is for the economic and technical communities of the world to inform their governments and regulatory bodies about the benefits and threats of the emerging information services era and the corresponding consequences to their national welfare.

Programme and Project Management in BT

A. J. ORR†, and P. MCKENZIE*

The Sovereign Project, resulting in the reorganisation of BT, provided the opportunity and incentive to review the company-wide quality of its programme and project management. This article focuses on how Divisional Project Management Support Units, with the common goal of radically improving project management, have tackled those issues which enable the effective management of cross-divisional programmes and projects.

INTRODUCTION

BT's capital investment programme, which has averaged around £3 billion per annum in recent years, represents over 7% of the total private fixed capital investment in the UK. Without that investment the rest of British industry would be denied the telecommunication infrastructure it needs to be competitive in the years ahead.

Personal Communications Division (PC) has the task of meeting increasingly demanding personal customer requirements in the UK; while Business Communications Division (BC) faces the challenge of serving the needs of business customers throughout the world. These two main customer-facing divisions are rapidly becoming the driving force for market-driven project-based activity across BT, and the majority of BT's major change programmes are owned by them.

Worldwide Networks (WN) has a mission to provide and operate high-quality, value-for-money networks to meet the demands of BT's customers in the UK and worldwide. Much of the £3 billion capital investment is spent on the network to promote growth, modernisation and enhanced functionality, and to enhance the opportunity for the customer-facing divisions to deliver BT's range of products and services to the market-place.

It will come as no surprise, therefore, that BT views professional programme and project management as an effective means of ensuring that it delivers what it promises, when it promises and at a price which represents value for money, which is in the interests of its customers, shareholders, suppliers and its own people.

The project management approach is, of course, no new innovation to BT. The company prides itself on its long-standing professionalism of the management of customer projects and its own internal technology-related projects.

The reorganisation of the company, effective from 1 April 1991, provided the opportunity and incentive to review the company-wide quality of its programme and project management and put in place a formal structure, together with processes and systems, to ensure quality and continuous improvement.

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* BT Worldwide Networks

TABLE 1
Definitions

Project	Group of related tasks, or activities, which together satisfy one or more objectives.
Project Management	The planning, directing and controlling of tasks or activities and resources with the objective of completing a specific project with predetermined parameters of quality, time and money.
Programme	A group of related projects which are managed in a coordinated way to gain benefits which would not be possible were the projects managed independently.
Programme Management	The coordinated support, planning, prioritisation and monitoring of related projects to meet changing business needs.

DEFINITIONS: PROGRAMMES AND PROJECTS

The science of project management can be summarised as giving absolute clarity on what is to be delivered, by whom, when, how and at what cost; and then controlling and managing the delivery.

It would be remiss in this article, therefore, to gloss over the terms *project* and *programme* and their management.

Table 1 provides definitions to aid clarity.

The key point is that a *project* delivers one or more objectives with associated benefits; a *programme* delivers the maximum benefit resulting from the effective coordination of related projects.

THE IMPACT OF SOVEREIGN ON PROJECTS AND PROGRAMMES

The Sovereign Project, resulting in the reorganisation of the company and completed on 31 March 1991, has added a new, critical dimension to the management of projects. Before Sovereign, BT divisions, for example, BTUK and

BTI, were relatively self-sufficient units which were able to deliver all aspects of a project from within their own resources. With the implementation of Sovereign, aimed at putting customers first through teamwork, no one division is, in general, able to deliver a major project without contracting out to other divisions. Thus, most major programmes comprise projects contracted out to more than one division, and most projects comprise work packages contracted out to more than one division. These are termed *cross-divisional matrix, programmes and projects*.

An essential enabler for the successful delivery of cross-divisional projects is a disciplined and commonly understood project management process.

Such a process provides a framework for the unambiguous statement of objectives and benefits, for understanding relationships between programmes and projects and, as a key to success, a common understanding of roles and responsibilities.

Figure 1 illustrates the typical organisation of a cross-divisional project. Key points are that:

- the *client* is responsible for justifying, funding, continually reviewing and ensuring the delivery of the benefits of the project;
- the *project manager* (appointed by the client) is responsible for delivering the project to the client's time, cost and quality requirements;
- the *contractor* is responsible for ensuring delivery by the contracted division;
- the *contractors' project managers* are, for the duration of the project, an integral part of the project team and are responsible for delivering their work packages as required by the project manager; and
- the project manager is empowered to work across organisational and functional boundaries.

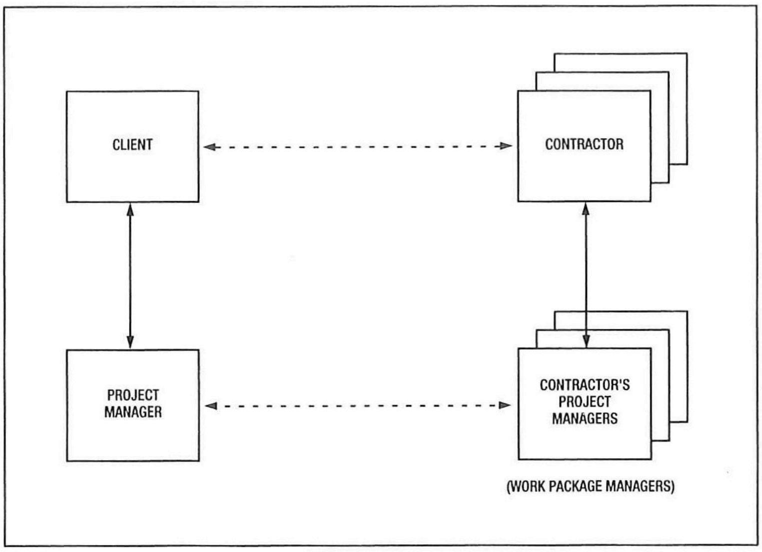


Figure 1
Organisation of cross-divisional project

GROUPING OF PROJECTS INTO PROGRAMMES

Ideally, projects exist within clearly defined programmes which meet business objectives. Thus, the programme definition provides goals and fit with business objectives, and sets boundaries and direction to its constituent projects.

Careful grouping of projects into programmes enables many other potential benefits to be accrued including, for example:

- resource/skill sharing,
- engineering/software commonality,
- research and development commonality,
- supplier commonality and potentially improved purchasing power, and
- shared costs across projects; for example, in marketing a related group of products.

Programmes themselves are also commonly grouped into higher-level categories, again with the aim of focusing even more closely onto the means of, and progress towards, achieving business objectives.

Worldwide Networks, for example, categorises programmes into one of two types:

(*a*) *Ongoing business programmes*: driven by growth, modernisation and routine replacement of the network in line with approved policies, technologies and suppliers to meet agreed demand and quality for existing products and services; for example, exchange modernisation.

(*b*) *Change programmes*: concerned with introducing systems, processes and technologies to improve customer service, increase income, reduce costs, and meet regulatory requirements; for example, national code change.

The focus in WN is shifting more and more towards change programmes and projects where responsiveness to the needs of the customer-facing divisions and product lines is going to be the key to BT's future competitive advantage. WN's future plans contain a raft of change programmes aimed at building a leading-edge competitive network.

Figure 2 illustrates, in simple terms, the relationship between business objectives and projects.

SUPPORTING CROSS-DIVISIONAL PROGRAMMES AND PROJECTS

The reorganisation of the company into its new divisions, and the new era of matrix programmes and projects, highlighted the need for establishing

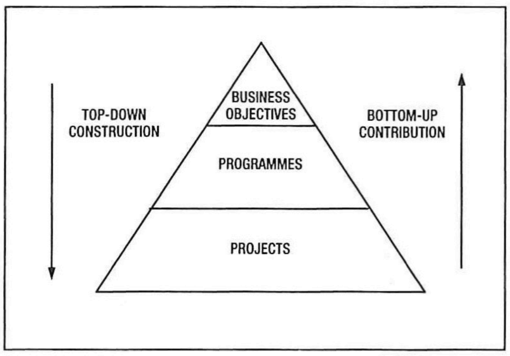


Figure 2
The relationship of projects to business objectives

a support organisation which would enable the divisions to work together to rationalise and introduce project management processes suitable for the matrix environment.

The outcome was the setting up of small centres of project management expertise within each of the new divisions which would be responsible for building the infrastructure, supporting clients and project managers and providing a coherent view of the division's programmes and projects aimed at delivering business objectives.

The design of the Programme Support Community was based upon three main building blocks:

- *A BT Programme Office* Located within Group Finance, the BT Programme Office would have specific responsibility for ensuring consistency and quality of project management across the company, for project management policy and leadership of the community.
- *Divisional Programme/Support Offices* Located within each of the key operating divisions, the Divisional Offices would have responsibility for defining and implementing divisional project-management policy.
- *Zone Project Offices* Located within the PC, BC and WN Zones, these project offices would have responsibility for supporting local management in all aspects of project management and implementation.

The period since the core organisation was put into place has been one of understanding, learning and evolution. Increasingly, the project management support organisations within the divisions have each evolved to meet the specific needs of their division.

The focus of the units and the organisation within the divisions depends upon many factors including:

- the type of work undertaken by the division and its component parts;
- the scope of the programmes and projects;
- the level of project management skills and understanding; and
- the complexity and number of interfaces both internal and external to the division.

The following brief insights into the BC Programme Office, the PC Programme Office and the WN Project Management Support Organisation illustrate how the support organisations are evolving to address the specific needs of the individual divisions.

BC Programme Office Focus

The BC Divisional Programme Office provides a focus for guidance on programme and project management quality recognising that support to clients and project managers in the early stages of a project is essential to success.

Helping the division to build the *big picture*, that is, understanding the relationships and contributions of BC's wide spread of activities (both UK and globally), is seen as an effective means of creating the right conditions for good teamwork. In this way, every project manager and project team member can see how their individual activities contribute towards the project, the programme and ultimately the division's business objectives.

BC, in common with other divisions, increasingly recognises that people are the key to successful projects, and that project management is largely about helping people to work together as a team to achieve common objectives. Thus people skills in professional project management are high on the agenda.

PC Programme Office Focus

The PC Programme Office focus has centred on building a firm foundation of project management support within the division. This has been based upon a community of Zone Project and Functional (Payphones, Group Logistics and Marketing) Programme Offices. The community is now largely in place and is beginning to address the target set by the Managing Director of:

- coordinating project and programme proposals to assist the PC Board in selecting those programmes and projects which make the greatest contribution to the divisional vision and mission;
- identifying linkages and dependencies between projects to maximise project synergy;
- assisting in the rigorous achievement of benefits.

Worldwide Networks Project Management Support

Within WN directorates, the organisational structure has been designed with project management as a key central focus to the planning and operational functions.

Within the WN directorates, Programme and Project Offices, plus associated support units, are responsible for improving the management of programmes and projects so that their time, cost and quality requirements are delivered. The focus is on helping to achieve greater standardisation and consistency and, in cooperation with BC, PC and BT Products and Services Management, improving the definition of programmes and projects to optimise their contribution towards business objectives.

Within the Zones, Works Programme Offices, for example, manage projects as well as the capital ongoing business programmes and ensure that project management principles are an integral part of day-to-day activities. As the interface between customers and the delivery units, the Works Programme Office is a central focus for problem solving, work allocations, communications and programme/project control in the WN Zones.

WN Programme and Project Offices also provide a channel for the two-way flow of information about successes, barriers, lessons and developments.

SUPPORT TO CLIENTS AND PROJECT MANAGERS

An essential role of the Programme Office Community is to provide help and guidance to clients and project managers in the application of the project management process. A key added value of the Programme Office Community stems from being uniquely placed (through its network) to provide advice on programme and project potential overlap, duplication, fit and interfaces with others across divisions.

Support to the client and project manager is generally provided by the Programme Office in which the project is cliented. Support to contractors (the work package managers) is generally provided by the contractor's Programme and/or Project Offices. However, notwithstanding these principles, the community takes a pragmatic approach to providing support, recognising that it needs to make optimum use of its total resource.

The type of support provided during the inception phase (see Figure 3) of a project ranges from advice on who should be the client right through to helping the client navigate the essential business processes that lead to formal approval of the programme and authorisation of the projects.

As projects emerge during the definition phase, the emphasis moves away from the client to the project manager, helping him/her to organise, define and plan the project, select the training necessary for the team and launch the project.

At such time as the requirements of the contractors have been defined by the client division and the client has obtained buy-in, the contractor's Programme and Project Offices are there to assist in the detailed planning of the work packages.

Throughout the process, communication across the Programme Office community is driven by the Programme Office in the client division.

PROCESSES FIT FOR THE MATRIX ENVIRONMENT

An integration of BT project management processes has been one of the essential requirements following the reorganisation of the company.

Project Management Handbook Process

The processes used in the management of projects, pre-Sovereign, have been reviewed by the new divisions and each has selected one which meets its needs. The most widely adopted process is that defined in the *Project Management Handbook*, originally a BTUK product.

All divisions are participating in a formal and comprehensive review of the *Project Management Handbook* and have radically improved the quality of its contents, including expanded descriptions of the process with everyday application models.

Particular successes have been achieved in improving the quality of the contents in respect of the Client Requirements Definitions (CRD) and Project Requirements Definitions (PRD) in response to the wide recognition that effort expended in the early stages of a project pays real dividends.

Figure 4 is a reproduction of the CRD example used in the *Project Management Handbook*.

The example assumes that the problem is: *insufficient leisure time for golf and family activities at the weekend.*

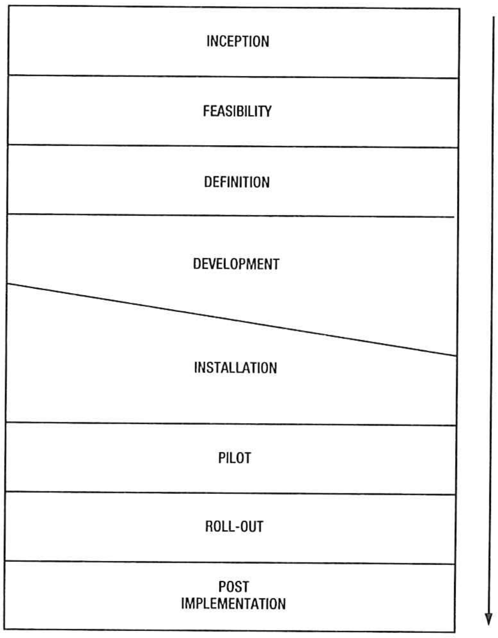


Figure 3
Project life cycle

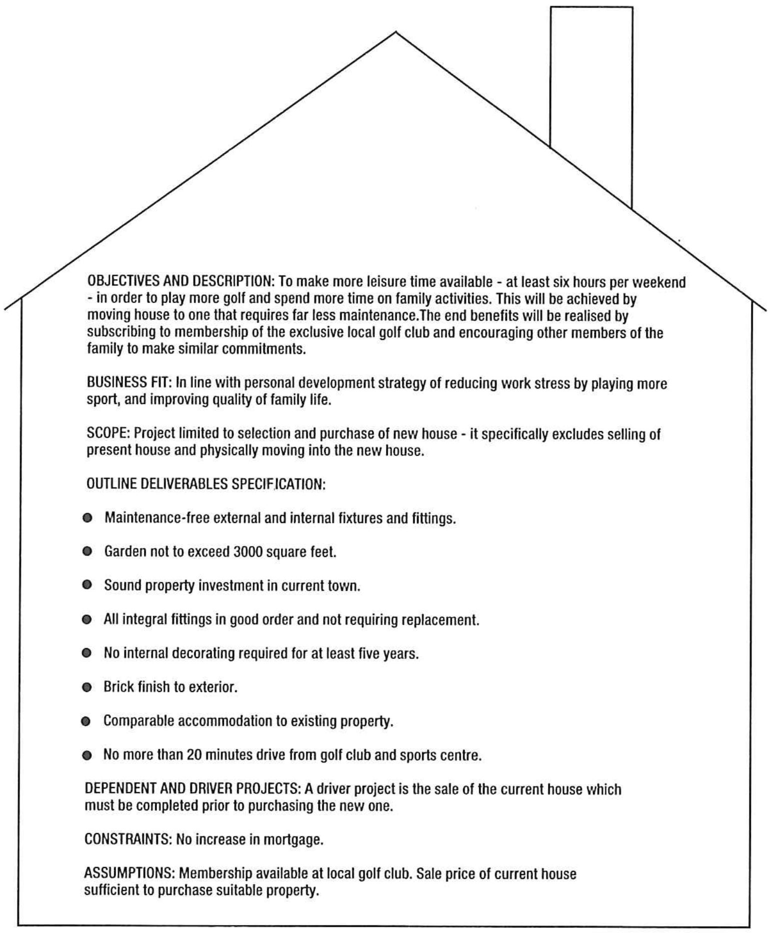


Figure 4—Client Requirements Definition—example

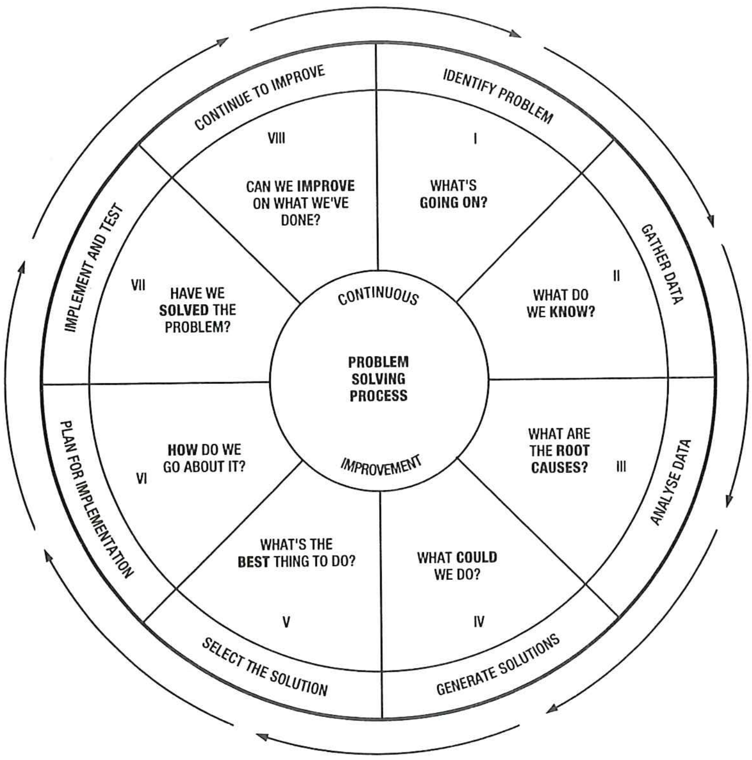


Figure 5
Total quality management (TQM) problem-solving wheel

A first step could be to use the problem solving process (see Figure 5). On reaching stage III, it will have been established that the root cause of the lack of leisure time is the time spent decorating/repairing the house and maintaining the garden.

The options can be evaluated—for example, refurbish house, employ handyman/gardener, or move house—and a final choice made on the preferred solution (Stages IV and V of the TQM problem-solving wheel). The example now assumes that the preferred solution is to move to a maintenance-free house with a small garden. It is at this stage that the CRD is raised.

Note that the original objective was to make more leisure time available, not to move house. This solution has been selected as the preferred means of achieving the objective. Moving house will not, in itself, achieve the objective. It is up to the client to capitalise on the house move to make more leisure time available, thus meeting the objective.

Thus, the client has stated his requirements in the CRD and it is now the responsibility of the project manager to investigate, discuss and record how well those requirements can be met in drawing up the PRD.

Project Management Framework

There are other project management processes, apart from the PMH, which are used within the company; for example, Telstar, which is used for information-technology developments.

The 'fit' between the various processes has been defined and communicated through the publication of a reference document called the *Project Management Framework*. This document enables the major divisions, using the PMH process, to communicate effectively with specialist units using non-PMH processes by providing a common terminology and reference life cycle on which other life cycles are mapped. Figure 6 illustrates the reference life cycle.

The company policy is that the client determines the project management process to be applied in consultation with the project manager. It is then the project manager's role to ensure that processes used by contractor divisions interface with the client's preferred approach: the *Project Management Framework* provides the common understanding necessary to define the interfaces.

Figure 6
How project management processes fit into the BT reference life cycle

BT REFERENCE LIFE CYCLE	BTUK PROJECT MANAGEMENT HANDBOOK	TELSTAR	PROMPT	BTI PROJECT MANAGEMENT HANDBOOK	PRINCE	TQM 5-STAGE APPROACH	BID AND PROJECT MANAGEMENT	BT REFERENCE LIFE CYCLE
1 INITIATE	INCEPTION/ CONCEPTION	INITIAL VET	(PRE-INITIATION)	INITIATION		PROPOSAL	PRE BID	1 INITIATE
		BUSINESS SURVEY	INITIATION		PROJECT INITIATION			
	FEASIBILITY	FEASIBILITY		FEASIBILITY				
2 SPECIFY	DEFINITION	PROJECT INITIATION		DEFINITION		ANALYSIS AND PLANNING		2 SPECIFY
		REQUIREMENTS SPECIFICATION						
		SYSTEMS SPECIFICATION	SPECIFICATION	AUTHORISATION			BID	
PRODUCE 3 BUILD	DEVELOPMENT	INTERNAL DESIGN	DESIGN	IMPLEMENTATION	PROJECT BY PROJECT STAGE DEFINITION	EDUCATION AND COMMUNICATION	IMPLEMENTATION	3 BUILD PRODUCE
	INSTALLATION	PROGRAM DEVELOPMENT	DEVELOPMENT					
		UNIT TESTING						
	PILOT	SYSTEM TESTING				IMPLEMENTATION PLAN		
		ACCEPTANCE TESTING		OPERATIONS ACCEPTANCE				
ROLL-OUT	ROLL-OUT	INSTALLATION	INSTALLATION	IN-SERVICE		IMPLEMENTATION /HOLD THE GAINS		ROLL-OUT
4 CLOSE	POST-IMPLEMENTATION	POST-INSTALLATION REVIEW	OPERATION	CLOSURE	PROJECT CLOSURE		PROJECT CLOSE OUT	4 CLOSE
				POST-IMPLEMENTATION				

(IN PRINCIPLE) PROJECT BY PROJECT STAGE DEFINITION EXAMPLE OF COMMONLY USED STAGES

PHASE/STAGE

Note 1: The above diagram shows a 'best fit' mapping of individual processes to the reference life cycle.
Note 2: The translation of one process to another will be subject to individual programme/project variations and therefore the direct relationship of process life cycles will not always be as illustrated.

Finance Processes

The project management process cannot, of course, live in perfect isolation from other business processes. It needs to link with the company's formal financial approval and authorisation processes and with the business planning process which culminates each year in the production of the *Annual Quality Plan and Budget.*

The Group *capital and project expenditure process* (owned by Group Finance) is a key enabler for successful matrix management and, more importantly, it has the ultimate objective of ensuring that the company obtains value for money and the achievement of planned benefits and returns on all capital and project expenditure. The process provides a framework for the authorisation, reporting and control of fixed asset capital and other project-related expenditure.

Key principles underpinning the capital and project expenditure process are:

- the integration of financial and project management processes (simply tracking spend against budget is no indication of value for money at any point in time);
- 'approval in principle' of programmes (a group of related projects) at the earliest practical stage;
- 'authorisation' of projects before any financial commitments are made, based on formal business cases supported by evidence of the application of professional, approved project management processes; and
- formal buy-in from contracting divisions to deliver their elements of projects and the planned benefits.

The group capital and project expenditure process operates for high capital spend projects. The divisions each operate similar processes in respect of other projects.

PROJECT MANAGEMENT SKILLS DEVELOPMENT

At the end of the day, projects are delivered by *people* who need to have varying levels of skill in applying the project management process.

Often, developing people to be effective in a project environment is related only to the use of tools and techniques; for example, the process and systems. With the predominance of the matrix project, the project manager's task is often to manage across functional and organisational boundaries without line authority.

An effective matrix project manager has to maintain excellent and diplomatic relations with his contractors, while directing the wider team and delivering the project as required by the client.

The most common approach to project management skills training is to bring together the project manager with his team, often with the client being involved as well. The Project Planning Workshop (managed by Training Division and contracted out to divisions) seeks to provide technical training in the process, develop relationships and establish leadership while, at the same time, making visible project progress. This event typically takes a CRD as the input, and works towards producing a first-cut PRD as the output.

The Core Training Programme includes a basic module on project management principles.

CONCLUSION

Effective project management requires discipline. It is not esoteric: it is simply the use of good practices which are commonly understood and fit for purpose, combined with good management, especially in respect of dealing with and managing people.

Successful project management enters the bloodstream at such time as individuals recognise it as helpful and not bureaucratic.

Effective programme management is a skill without which business objectives are unlikely to be met.

Excellent programme and project management are, without doubt, considered by BT to be critical success factors. It is expending time on getting the portfolio right and driving up the quality of project management through improved processes, systems, skills and support.

ACKNOWLEDGEMENTS

The authors wish to thank Martin Brenig-Jones, BC Programme Office Manager, and Eddie Goodwin, PC Programme Office Manager, for their contributions on Business Communications and Personal Communications respectively.

Biographies

Angela Orr has been closely involved with projects and project management throughout her career. Initially she was involved in systems analysis and design, working on a wide range of computing projects. Six years ago she turned her attention to project management, and has for the past three years been actively involved in the development of project management methodologies and training, and latterly in providing project management consultancy to major programmes in BT Group Headquarters. She is a member of the BT Programme Office.

Peter McKenzie joined the Post Office in 1971 in Brighton, South East Region. In 1976 he moved to Management Services in THQ, London, where he was employed on engineering-efficiency assignments and computer-application projects, primarily on common-control exchange maintenance and electronic-equipment repair. In 1983 he joined National Networks Trunk Services with responsibility for regional resource utilisation and network quality of service. In 1985 he was with Trunk Services and had responsibility for operations and maintenance of interconnect projects with other licensed operators and managed services within the Network Operations Centre. He joined the Network Integration Division of Network Planning and Works in 1989 and was subsequently appointed Manager, Network Programmes. He is currently the Vice-President of the Associate Section of the IBTE.

Development of the National Code Change

N. A. C. McLEOD†

When the present numbering plan was developed in the 1950s, it was expected to last for 50, or perhaps even 100, years. Advances in technology and the emergence of new services in a liberalised telecommunications environment are creating a demand for numbers and codes that cannot be sustained by the present UK numbering arrangements. This article discusses the factors that were taken into account in developing the National Code Change as the solution to take numbering for telecommunications into the twenty-first century.*

INTRODUCTION

In many countries throughout the world, telephone network numbering plans are undergoing major changes to enable them to meet the demands imposed by growth and the emergence of new services. Throughout its life, the UK numbering plan has seen relatively few major changes. The national change of most significance to customers occurred in the 1965–70 period when the alphanumeric codes were replaced by all-figure codes. Most of the activity has been confined to the evolution of local numbering schemes coincident with exchange replacement and, more recently, the modernisation of the network with digital switching equipment. The London Code Change of May 1990, although of national significance, was essentially a local number scheme change.

In the UK, the changing regulatory environment, which has introduced competition in the provision of networks and services and accelerated the pace of change, has brought an additional dimension to the pattern of demand that has contributed to the earlier than expected demise of the present national numbering plan.

REQUIREMENT

A fundamental requirement in the management of numbering plans is the continuous availability of numbers, not only in quantity but also in terms of their suitability for the intended purpose. A BT study as far back as 1982–3 identified that the major concern for the future of the UK numbering plan was its ability to continue to make available national codes for the new services that were beginning to emerge. At that time this was most evident in the area of mobile communications, where plans were being laid for the introduction of cellular radio and advances in technology were foreseen that would bring the concept of personal communicators nearer to reality. On the other hand, local numbering capacity was, for the vast majority of locations, considered to be more than adequate to meet future needs. The few local areas that might need an increase in capacity were also a potential source of further demand on the limited number of national codes.

The 1982–83 study established that the key design requirements for a future numbering scheme were that it should have capacity, flexibility and the potential for longevity. A further requirement, which arose largely from the introduction of competition, was that of the quality of the codes and number blocks that could be made available. For example, some new network operators look for sequential runs in codes available for allocation to their services in anticipation of growth, others look for memorable combinations of digits.

These requirements have endured through many studies, not least being the investigation carried out by the Telecommunications Numbering and Addressing Board, which was set up to fulfil the required consultation process stipulated in the BT Licence.

Developing and implementing a new national plan is a task of considerable magnitude. While the numbering plan has its origins and is embedded in the network, its influence, and therefore the impact of change, is wide ranging. In the first instance, any change must be technically and operationally achievable, at an acceptable cost and in the available timescale. In modern telecommunications network operations, there are three areas where technical considerations need to be addressed in a numbering plan change: the switching systems and network configuration, the computer support systems for planning and managing the network, and the computer systems used for administration and customer support.

In the final analysis, however, it is the considerations relating to customers, both present and future, that have the greatest influence in the choice of a solution. For example, customer premises equipment, from the telephone instrument upwards, now includes sophisticated features based on the storage and recognition of number information. It is therefore a prime requirement that the change is easy to understand and apply. Additional benefits that flow from this are that the change is easier to explain and the incidence of misdialling using the old procedures is likely to be minimised. The possibility of misdialling cannot, however, be ignored. It is there-

† BT Worldwide Networks

* McLEOD, N. A. C. Numbering in Telecommunications. *Br. Telecommun. Eng.*, Jan. 1990, **8**, p. 225.

fore essential that the implementation arrangements provide for the interception of such calls so that they can be routed to announcements that give customers guidance on the new procedures.

The criteria against which the options for changing the numbering plan had to be tested were:

Design Requirements

- Capacity.
- Flexibility.
- Potential longevity.
- Ease of understanding.
- Ease of use.

Implementation Requirements

- Minimised impact on customers.
- Technically achievable in network, switching systems and computer support systems.
- Misdialled call interception and routing to announcements.
- Achievable in an acceptable timescale.

THE IMPLEMENTATION OPTIONS

While the design objectives set out the framework within which the numbering plan was required to be developed, it was the implementation considerations that defined the practical limitations within which any development could be achieved and provided the main focus for the study of the options. Two possible approaches for changing the numbering plan were available: rearrangement of the existing 9-digit scheme or increasing the significant number length to 10 digits.

Rearrangement of the 9-Digit Scheme

There can be no doubt that the present 9-digit numbering scheme, with a theoretical capacity of 1 billion numbers, has the potential to meet that aspect of the design criteria. Where the scheme falls short is in its lack of flexibility of application. This derives from the historic structure and application of the scheme, which was designed in the context of the customer requirements, network configuration and system capabilities of an analogue network.

An obvious option for the creation of additional codes is the amalgamation of numbering areas where there is low utilisation of the available capacity. Codes released in this way would reflect the random distribution to be found throughout the network, and therefore it would be unlikely that blocks of sequential codes would be made available. This could be remedied by targeting particular codes for recovery, but this would almost certainly mean making changes in numbering areas with substantial numbers of customers.

In practice, the code-recovery option could be achieved only through a programme of changes running over a number of years. During that time, changes of increasing complexity would be required, probably involving some customers in both code and number changes in order to create the space for the next change.

Increasing the Number Length to 10 Digits

When the option of increasing the maximum length of the national significant number from 9 to 10 digits was being considered, there were two possibilities for the position of the additional digit: in the middle of the number after the numbering area code or at the beginning of the area code.

Putting the additional digit in the middle of the number can bring about an increase in capacity in two ways. Placed at the beginning of the local number (Figure 1(*a*)) it would bring relief to the local area numbering schemes. There is, however, very limited application for this approach and the end result would be the creation of large amounts of capacity in the areas where there was no need. There is also the potential difficulty in managing the call-trapping arrangements for calls dialled using the old numbers after the change. The practical realisation of this requires the additional digit to differ from those used as the existing first digits of local numbers and this would not always be possible.

(*a*)	0 ABC XDEFGHJ	Part of the local number
(*b*)	0 ABCX DEFGHJ	At the end of the national code
(*c*)	0 XABC DEFGHJ	At the beginning of the national code

Figure 1—Options for the placement of the additional digits

Attached to the end of the numbering area code (Figure 1(*b*)) the additional digit would have the effect of increasing the number of codes. While this approach would be easier to implement, 1 or 0 could be used as the additional digit in the first instance, the use of the new 3- and 4-digit codes would be limited to a significant extent and perpetuate the incoherent structure of the existing numbering scheme. There would also be little opportunity for creating customer-friendly numbering schemes for new networks and services.

Putting the new digit at the beginning of the national code, after the prefix digit '0', (Figure 1(*c*)) would offer the greatest scope for creating a large-capacity flexible numbering scheme. New initial digits, when brought into use, would not be constrained by the existing geographic structure, and the opportunity would therefore be available to design numbering arrangements appropriate to the networks and services requiring them. This therefore became the preferred solution. The problem was to devise an acceptable implementation plan.

Initially, there were few options for implementation of the 'digit-at-the-front approach' and all of them required a series of changes staged over a number of years. The problem was that the existing national code structure used all the available initial digits. Early stages of the change process would therefore have to be directed at

clearing space for the full implementation of the plan. From a customer perspective this was considered to be unacceptable since the change would be prolonged and complex making it difficult to publicise and understand. Considerable resources would have to be deployed to counter the potentially high level of misdialled traffic during the change. The clear preference was for a single-stage change.

The situation was dramatically changed by the decision to resolve the impending exhaustion of the London numbering capacity by replacing the national dialling code 01 with 071 and 081. The release of the initial digit '1' created the ideal platform from which to launch a change to the numbering plan. It also raised a question as to whether a change was needed at all! Re-examination of the issues, however, showed that, while significant benefits could be gained in the short term from the reuse of the 1XX code capacity, there was still a strong likelihood of an increase in number length being required by the end of the century. The window of opportunity for a 'simple' change would therefore have been lost.

NATIONAL CODE CHANGE

The planned change to the national numbering plan is shown in Figure 2. The change will be achieved by inserting the digit '1' after the prefix digit '0' to provide a new leading digit for all numbering area codes; that is, those national codes that are allocated to identify the geographic locations of the fixed public switched telephone network. National codes allocated to the 'non-geographic' applications such as cellular radio, premium rate services etc. will not be included under digit '1' since these services are likely to be identified by other leading digits at a later stage in the development of the new numbering plan.

Figure 2
Plan for the National Code Change

To put the additional digit '1' at the beginning of the PSTN numbering area code:

0 1ABC DEFGHJ

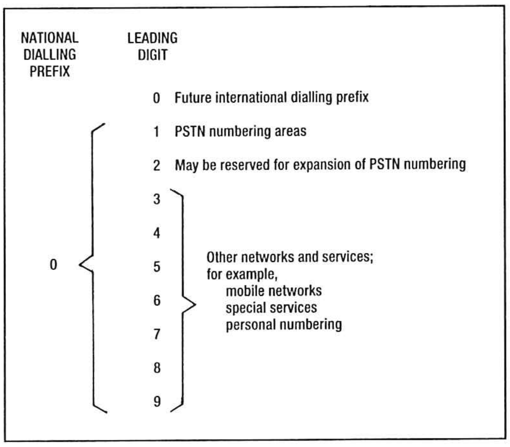
Examples:

Birmingham 021 246 7890 becomes 0121 246 7890

Brighton 0273 805469 becomes 01273 805469

Non-geographic codes (for example, cellular radio 0836, 0860) are not included under digit '1'

Figure 3
New numbering scheme



This scheme enables the main customer-related criteria to be satisfied. The change will be easy to explain and to understand, and consequently the risk of confusion reduced. The interception of misdialled calls and routing them to announcements after the change will be relatively straightforward since, with the exception of the few non-geographic codes, leading digits 2–9 will be unoccupied.

FUTURE DEVELOPMENT OF THE NUMBERING PLAN

The National Code Change, by opening up a full range of new leading digits as seen in Figure 3, creates a platform for the development of coherent and lasting numbering arrangements in the UK. As experience already shows, this does not necessarily create an inexhaustible supply of numbers. If the UK is to avoid going through number plan changes of the magnitude of the National Code Change in the future, then the new capacity must be used with care. The needs of customers, service providers and telecommunications operators must be balanced against sensible policies for the conservation and evolution of the numbering plan.

Attention is currently being focused on the numbering requirements of the non-geographic telecommunications services. These are seen to fall into two main categories: mobile services and specially tariffed services. The questions to be resolved for each of these is whether or not they warrant the allocation of a leading digit as a unique identifier and to what extent considerations such as product branding should feature in the allocation of codes to service providers.

The requirement for personal numbering is also coming nearer to realisation with the international standards now being developed for a universal personal telecommunications (UPT) service. After the National Code Change, there will be full scope to develop the new numbering scheme so that all telecommunications services, including UPT, can be accommodated within universal numbering arrangements that use familiar and common dialling procedures.

The National Code Change provides a unique opportunity for creating a numbering scheme that meets the needs of the evolving competitive environment for telecommunications.

Biography

Alistair McLeod joined the Post Office in September 1958 as a Youth-in-Training in the Edinburgh Telephone Area. Since moving to the Engineer-in-Chief's Office in 1964 as an Assistant Executive Engineer, he has worked on signalling system development, the specification of requirements for trunk switching systems and customer interfaces for the ISDN (IDA) pilot. He is currently Numbering Strategy Manager within the WN Network Strategy Department, where he is responsible for the management and strategic development of numbering and addressing for BT, a role with which he has been associated since 1981. He is an Incorporated Engineer and a member of the IEEIE.

Implementing the National Code Change

A. CROFT†

This article outlines the project management process that has been put in place to implement the national code change whereby the numbering scheme in use in the UK would be extended to ten digits by the inclusion of an additional digit at the beginning of the national code.

INTRODUCTION

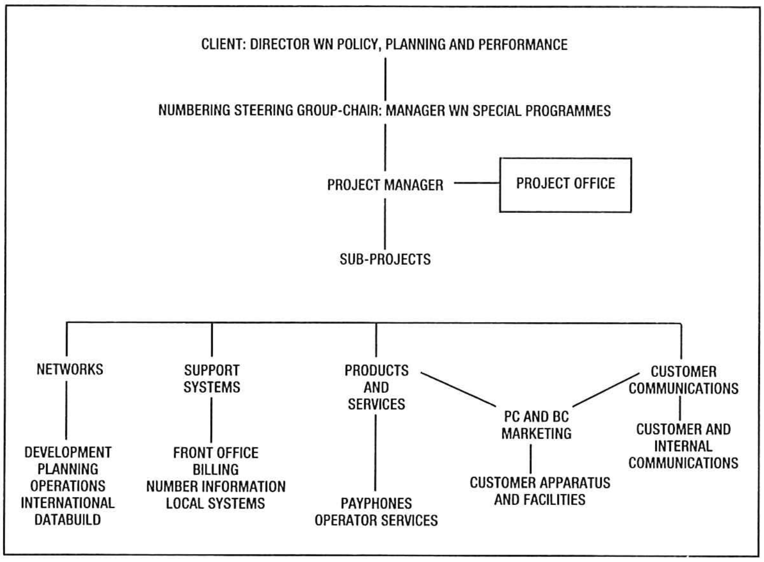
When the present numbering plan was developed in the 1950s, it was expected to last for perhaps 100 years. An increasing demand for new services has meant a reappraisal of the numbering arrangements in the UK[1] and the decision to change the national codes by the inclusion of an additional digit at the beginning of the code. This article outlines the project management process being set up and some of the key activities required to implement the national code change.

LEARNING FROM EXPERIENCE

The National Code Change (NCC) project was initiated while the London Code Change[2] was still being implemented. The structure of the London Code Change project had proved successful and it was decided that, as far as possible, the NCC project would be organised along the same lines. The NCC would not face the problems encountered in London by creating two areas (071 and 081), but on the other hand would affect the whole country. The many lessons learned during the London Code Change are proving invaluable in tackling this new task.

SCOPE AND ORGANISATION OF THE PROJECT

Within BT, the project will affect everyone—if not in the implementation, then in assisting customers or as users themselves. Telephone numbers are an integral part of the network, but they are also used in support systems (for example, Customer Service System (CSS)), in publications (directories and leaflets), in customer apparatus (for example, call barring), and in every BT function (for example, notepaper and telephone calls). The project organisation has to embrace all these and more. The structure is, therefore, to have a project team representing broad business functions working to the project manager, who in turn reports to the Numbering Steering Group and to the lead client—Director, Worldwide Networks Policy, Planning and Performance. (See Figure 1).



BC: BT Business Communications
PC: BT Personal Communications
WN: BT Worldwide Networks

Figure 1
Project organisation

FEASIBILITY STUDY

The first task of the project team was to scope the project and carry out the feasibility study. It was important that the full implications were known before consultation with the Telecommunications Numbering and Addressing Board (TNAB) and the Office of Telecommunications (OFTEL) became too advanced. The study assumed what proved to be an impossible target date of mid-1992 for the code-change, as this was thought to be the absolute earliest time that any such change could be completed. This was an onerous target, but it was important to establish realistically what the earliest implementation date could be. This assessment would need to stand up to scrutiny by the regulator who was under some pressure to bring an early solution to the shortage of codes.

The Networks sub-projects (Inland, and International) had to consider three aspects:

(*a*) modifications required to handle the additional digit;
(*b*) capability for handling old and new codes during the parallel running period; and

† BT Worldwide Networks

(*c*) capacity to handle the misdialled calls after the change.

Each switch system had to be considered against these criteria. Each system has different requirements and different solutions.

Simple analogue systems (TXS and TXE2) cause no concern as they do not store or process the dialled digits. Crossbar systems (TXK1 and TXK3) need modification to store and forward the extra digit. Modern systems which store and process the digits (TXE4 and TXD) require development to give the necessary extra functionality.

The switch and transmission demands due to the misdialled calls after the change can be accommodated within the network margins and so are not significant factors, although it is necessary to ensure that the announcement capacity is adequate.

The support systems team had to trawl through all BT computer systems to establish those which process or hold telephone numbers. Some 150 such systems were identified. Key areas are billing, CSS and directories, but all the 150 will need to be modified or replaced before NCC day. A strategy for conversion is needed and facilities for handling old and new numbers (for example, when customers dial the new codes in advance of NCC day).

The customer communications responsibility also embraces internal communications. A plan for the communications activities was outlined to embrace major customers, other customers, (at home and overseas), special interest groups (representative bodies, user groups etc), specialist BT people (account managers, customer service duties), public enquiries, and everyone in BT. One requirement that was established at this stage was the importance of setting and announcing the date of the change-over at the outset so that customers and staff can focus on that date.

Products and Services embraces the customer premises equipment (CPE), payphones, Network (Star) services, operator services and all other BT offerings. For each service it was necessary to assess the impact of the code change and to produce outline plans to implement any necessary action.

The outcome of the feasibility study was that the 1992 date could not by any means be achieved. The absolute earliest NCC date would have to be 1994, and even that is a challenging objective.

FIXING THE DATE

The choice of actual date was governed by several factors. Ideally a long weekend (a bank holiday) should be selected. This gives customers a natural break in their business use. It gives BT more time to convert systems 'out of office hours'. It gives a low level of usage at the time of change-over and a slow build up in the days after the change as many businesses extend the holidays. The Christmas and New Year period has an abnormal calling pattern—and getting staff to work over that period would be difficult. Thus Easter Sunday was chosen. To avoid the confusion that sometimes arises from the use of midnight, it was decided to set the exact time of the change as 01.00 hours on the morning of Sunday 3 April 1994.

KEY ACTIVITIES

Development and roll-out of the necessary features for System X and AXE10 digital exchange systems and for TXE4 are crucial to the project. Analogue exchanges, in particular the remaining crossbar units (TXK1 and TXK3), require a modification to store and forward the extra significant digit, and this will be an in-house modification. Network support and test systems require appropriate changes. Liaison with other network operators will be necessary in order to coordinate data changes and testing. International switching centres will require data changes and announcement facilities. Overseas administrations are being asked to provide announcements in the country of origin wherever possible.

Modifications are being developed for all computer systems which hold or process telephone numbers. The billing and directory systems are the two major customer-facing systems which must be changed on time. The billing system must correctly charge for any calls made using the new codes in advance of the formal change and so must be ready by the time of the first data changes in the network. In order to be consistent with the policy of not encouraging early use of the new codes, itemised bills will show calls against the 'old codes' until the day of change-over, even if the new code has been dialled. The directory systems will convert the codes both for the printed directories and for the directory enquiry service, which will change the automatic voice announcement at the time of the NCC.

There will not be a special reprint of telephone directories, but it is important that those issued immediately before the code change show the new codes. Earlier issues will have special notices advising callers of the pending change.

Public payphones will require modification to the fault monitoring system to enable the automatic dialling for fault reporting to use the new codes. Other customer equipment which stores and or processes numbers (for example, short code dialling, call barring, carrier selection) will need reprogramming and may need hardware changes. Reprogramming can often be carried out by the customer, but a survey will be carried out to identify those customers who need practical assistance from BT. Network (Star) services customers will need to ensure that they use the correct codes when setting up call diversion. Operator Services will need to train their people to respond to customer requests in the new form and to give advice where necessary.

A major part of the project is the communications campaign. The campaign must cover custo-

mers (business and residential), BT people (customer facing and others), special interest groups (political and technical) and people overseas who make calls to the UK. The main campaign will run from 'Two years to go' through to and beyond the NCC day in April 1994. A customer helpline is in operation during normal hours and this will be constantly monitored to ensure sufficient coverage as the campaign builds up. The Connections in Business bureau in Bristol will handle the first-level calls, using scripts provided by the project manager. Calls which cannot be resolved from those scripts will be passed to the second-level helpline in the project office.

CUSTOMER ISSUES

The smooth London change-over has shown that BT can implement such a major change without any significant disruption for customers. The experience and research shows that customers need:

- reassurance that BT will do everything it can to help;
- clear simple messages;
- time to plan and to implement such items as printing and signage thus minimising cost to customers;
- guidance on making changes to programmed numbers and when this can be done (there is no need to stay up until 1.00 am);
- offers of help where engineering action is necessary (for example, on call barring);
- easy access to information, for example, from the helpline, with a consistent message from all points of contact; and
- helpful recorded announcements giving the correct code (to cover those codes which have changed and those which have not).

As might be expected, the customers with greatest concern will be businesses in London who have already been through a change of code in 1990. Although it is still fresh in the mind, there will be almost four years between the changes and the national code change will not present any real difficulty.

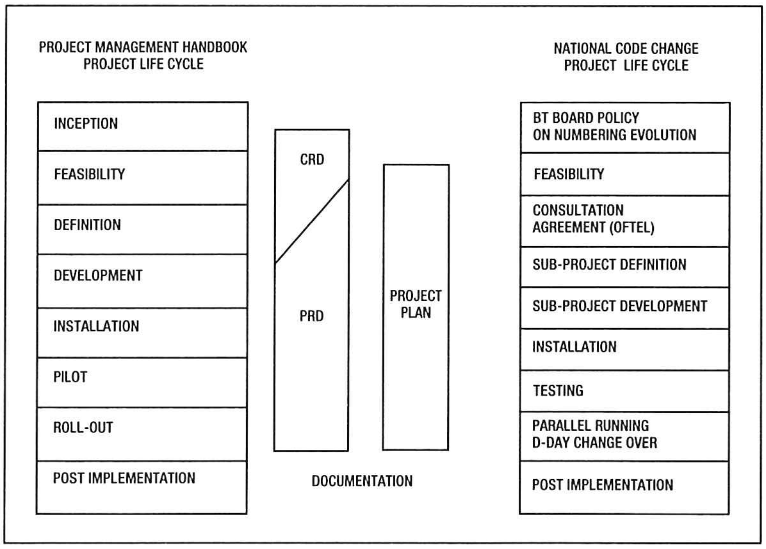
PROJECT MANAGEMENT PROCESS

The project has to bring together plans and information across the business. Different work areas use different practices and different systems. The coordination of all these activities and the identification of the dependencies across work areas are crucial to success. In each work area, work packages with clear deliverables have been defined and broken down into individual tasks. For each package, the dependencies, in and out, have been recorded.

The top-level plan is being recorded by using the Hornet Project Management software on standalone PCs. Two versions of the plan are held on different PCs: one being the approved master plan; the other being the working model. Apart from the security that this provides, the model can be used to assess the impact of any changes on the total plan before the changes are accepted in the master. The system is used to generate requests for progress reports on all current activities and those due to commence within two months. The requests are sent to the sub-project managers who fax the returns so that the model plan can be updated and, if accepted, transferred to the master plan. The size and complexity of the project and the range of systems in use across the business precludes any direct automated linkage between the project office system and individual sub-project systems.

Cost-tracking procedures have been established to pick out costs from the on-line systems in Networks and off-line from other areas. Work package progress and spend reports are therefore available for the monthly project meetings and the quarterly Steering Group meetings.

The specific phases in the *BT Project Management Handbook* do not apply to this project. For instance there cannot be a pilot stage, one area cannot be changed in advance of the others, and certainly cannot be changed back again. The basic principles are, however, being applied, and financial authorisation is being sought on an annual basis, see Figure 2.



CRD: Client requirements definition
PRD: Project requirements definition

Figure 2
Outline of national code change project

IMPLEMENTATION

The implementation has to be carefully arranged so that each step occurs in the correct sequence. For example, the billing system must be able to charge for calls by using the new codes before the first routing data changes are implemented in the network. Data changes for routing must be made in the correct sequence such that a call routed from one exchange will not be rejected at the next. The outgoing data changes must be complete

before the calling line identity (CLI) changes are made as it is a feature of the integrated services digital network (ISDN) that return calls can be made to the CLI number in order to verify the authenticity of the call origin.

Routing data changes will commence up to a year before the change and the target date for 'network ready' is November 1993. This will fit in with inter-network testing with other operators and leave the way clear for a period of parallel running. This will permit specialist changes such as the autodialling component in security and care alarms.

Computer support systems will generally change as a big-bang operation after close of office on 31 March 1994. Directory enquiry systems will quote the new number from as close to the NCC time as possible.

Throughout all this time a full customer communications campaign will be maintained. Letters to major customers, bill stuffers, leaflets etc. will be backed up by an advertising campaign climaxing on 3 April 1994. The sequence will start with general awareness and the need to prepare, through detailed planning (for example, printing changes, CPE changes) to implementation. The campaign will be adjusted in the light of regular market research which will assess the levels of awareness, so that the correct balance is attained. Too little publicity will lead to customer dissatisfaction and possibly high levels of misdialling, too much will lead to claims of overspending, and could in itself obscure the key message—simplicity.

CONCLUSION

In summary, the project affects everyone in the UK. BT has the the plans in place and the commitment to make it happen on time. Everyone has their part to play so that, on 10 April 1994, one week after the NCC, everything from the customers' point of view will have gone so smoothly that it will be seen as a non-event.

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1 McLeod, N. A. C. Development of the National Code Change. *Br. Telecommun. Eng.*, Jan. 1992, **10** (this issue).

2 Banerjee, U., Rabindrakumar, K., and Szczech, B. J. London Code Change. *ibid.*, Oct. 1989, **8**, p. 134.

Biography

Alan Croft is Project Manager for the National Code Change. He joined the then Post Office in 1964 as part of the Traffic Planning Division in London South West Area working on exchange capacity utilisation and number allocation. He then worked in the Traffic Engineering group in the Development Department specifying requirements for traffic measurement facilities before transferring to the Network Planning Department to work on the trunk routing plan and was responsible for the development and implementation of the traffic routing and management system. Work in the number planning and digital exchange department led to an involvement first in local numbering and then in the national numbering project. He was appointed project support manager when the NCC key project was established, and took over as project manager following the Project Sovereign organisational changes.

BT Energy Overview

C. L. WRIGHT†

The effective management of energy resources is an important aspect of business efficiency and BT's contribution to the wider environment.

The company's expenditure on energy now exceeds £115M, over half of which is incurred by the network. This represents over 9% of BT's retained profits and is increasing in terms of energy consumed.

Most of BT's energy costs relate to the purchase of electricity (see Figure 1). BT is already taking advantage of competition in the electricity supply industry to secure improved electricity prices for sites with consumptions of above 1 MW. To date, savings of 25% have been made on electricity costs for these sites in a climate of real price increases in unit costs generally. This will be extended to sites above 100 kW in 1994 and to all sites in 1998.

Technical innovation, combined with new commercial practices, offers many opportunities for significant reductions in energy costs. Energy consumption must be considered an important issue when options for new building and equipment designs are evaluated. This is especially important as all energy consumed generally requires energy-hungry cooling equipment which itself is expensive and occupies accommodation with overheads.

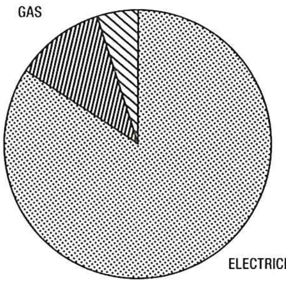

Figure 1—BT's energy expenditure (1990/91)

The BT energy bill represents several hundred pounds each year per employee, and much of this is controllable such as lighting, heating and office equipment. Switching off such equipment when not required is a simple energy-saving action that can now be applied by all BT people. Closing doors and windows and not wasting hot water are all personal actions that can be taken which will help control BT's energy costs.

The commercial advantages of improving energy efficiency are clear. Simple investments in energy saving can often produce very significant savings in operating costs and consequently in bottom-line profits. However, energy consumption is not only an economic consideration, but the production and use of energy is one of the single biggest causes of damage to the environment. The activities of commerce and industry are currently responsible for half of the emissions of carbon dioxide in the United Kingdom. This is one of the main contributors to global warming. It is expected that regulation will require a reduction in harmful emissions such as carbon dioxide from electricity generators to be contained below 1990 levels. This is the subject of a Government White Paper *This Common Inheritance*.

BT plans to make a corporate commitment to the Government initiative on energy management in the first half of 1992. This will give a high priority to energy management, publish a corporate policy statement, ensure that energy management responsibilities are understood, increase awareness of energy efficiency among BT people, set and review energy performance targets, hold regular reviews of achievements and report performance changes and improvements to BT people and shareholders.

BT plans to be a world leader in energy management and to be the role model for best practice. In order to achieve continuous improvement in the management of energy, an Energy Management Policy Group has been established and this will, in turn, advise the company's Environmental Policy Steering Group.

The following two articles in this issue of the *Journal* describe some of the plans and achievements to date. It is important that everyone in BT understands that they have a potential impact on BT's energy consumption. Continuing interest in the company's effectiveness in energy management will help meet the business challenges of the 1990s and the company's wider social obligations as a major consumer of energy resources.

Biography

Chris Wright is the manager of the Engineering Support and Launch department responsible for introducing new technology into BT's core network. He joined BT in 1971 as a graduate in electronic engineering. After specifying requirements for international switching centres, he worked abroad for several years in telecommunications software development and consultancy. On return to the UK he has held a number of senior operational engineering management positions in BT.

† BT Worldwide Networks

BT's Energy Use

G. S. CLARK, and A. C. BEALING†

Energy management is becoming even more important as the threat of climate change hangs over us all. This article looks at how BT is using its energy now, and how its energy requirements have changed over the years.

INTRODUCTION

Interest in BT's use of energy has accelerated over the past two decades in line with the increased use of, and dependence on, electrical energy. Pressure to conserve and manage energy has now become a moral as well as an economic consideration, and BT's customers and shareholders are now increasingly being made aware of the link between energy use and the environment.

BT in its previous guises (the General Post Office, the Post Office and British Telecom) paid attention to energy management by establishing posts such as fuel economy officers. The energy crisis of 1974 formalised energy management with the introduction of field energy managers and, for the first time, comprehensive annual energy statistics were produced. During the 1970s and the 1980s, modern technology started to influence energy management particularly through control, heating and lighting systems. Any savings on energy expenditure made in these areas over this period were countered by an increase in the electricity consumption of the telecommunications system, as a result of its rapid modernisation with electronic equipment, which usually consumed more energy than the electromechanical equipment that it replaced.

In 1986, energy management was reinforced by a government initiative known as *Monergy Year.*

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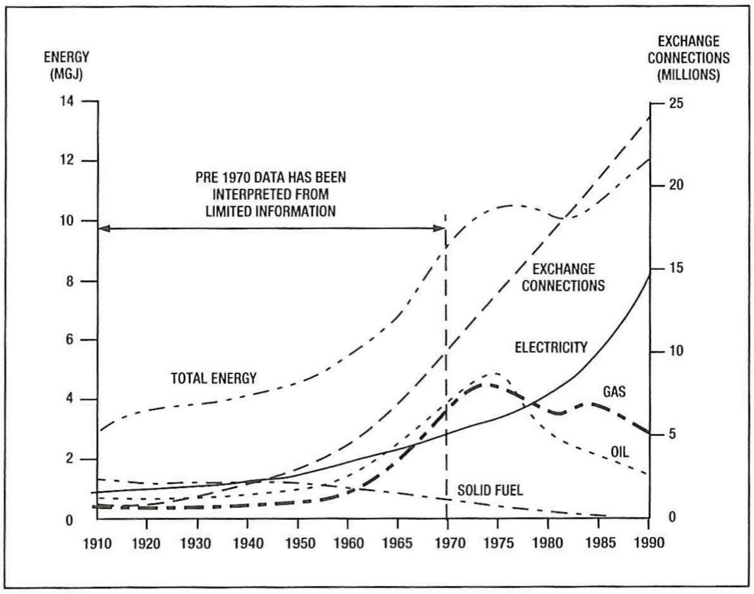
Figure 1
Energy and exchange connections



BT played an active part in this with an energy awareness campaign which first targeted senior managers for eventual dissemination throughout the business. Energy managers in BT were given videos and other briefing material to help pass the message on to people in their district.

The energy manager has a variety of tasks: education, consultancy, data gathering, monitoring and auditing. The use of energy is not always apparent, and the energy manager's main function is to determine where energy is being used wastefully, and to take corrective action. Energy use may be wasted due to poor design or poor housekeeping, and a quite different approach is required in each case. BT has around 25 energy managers, each dealing with up to 1600 sites. They are assisted by a computer-based energy monitoring and targeting system.

PAST ENERGY USE IN BT

The public telephone service started in the late-1800s, and as it was a manual system, most of the energy used was in the form of solid fuel and town gas for heating, with electricity and town gas being used for lighting. In 1912, Strowger electromechanical systems started to replace the manual systems and, from then, electricity became the vital energy source that it has remained ever since.

Valve repeaters were first introduced on long-distance trunk routes in 1920, and this allowed the use of a lighter gauge of cable. By 1930, it became economic to use valve repeaters on the shorter trunk and junction routes. The energy demand of these valve repeaters significantly increased the electricity consumption at each site. For the next few decades, new installations of both switch and transmission equipment increased the electricity consumption in line with the growth of the business.

Mechanical ventilation, with its associated energy demand, was introduced in some cases to dissipate the heat produced by the transmission part of the exchange.

Installation of electronic exchanges commenced in 1963 and, unlike the earlier valve systems that tolerated high temperatures, the new equipment contained closely-packed temperature-sensitive solid-state electronics. This made energy-consuming cooling systems a necessity that is still with us in the present digital era.

Figure 1 shows, for the period 1910 to 1990, the energy used from electricity, gas, oil and solid

fuel, the total amount of energy used and the number of exchange connections.

The power plant that provides the electrical energy for exchange equipment has also changed over the years. Power plant is designed not only to provide a nominal –48 V DC supply to the equipment, but to ensure that, in the event of a mains failure, the exchange continues to operate. For short breaks in the mains supply, a battery back-up enables the exchange equipment to continue operating; longer breaks are backed up by means of a diesel generating set. Modern technology has enabled batteries and rectifiers to be accommodated in equipment suites instead of in a separate power room.

PRESENT ENERGY USE IN BT

Energy Sources

The energy that BT uses is now obtained from three main sources: electricity, gas and oil.

- Electricity is mainly used for network equipment (including its cooling), heating, lighting, catering, personal computing, mainframe computing and other building services such as lifts.
- Gas is mainly used for heating and catering.
- Oil is mainly used for heating.

A very small amount of solid fuel is still used, but as this comprises only 0·1% of the total, it can be ignored for practical purposes.

Over the last ten years, BT's electricity consumption has doubled. Figure 2 shows the electricity consumed by BT from 1980 to 1990. The increase in consumption is due to increased telecommunications traffic and because, as already stated, modern digital exchanges use more energy than Strowger exchanges. Although the maximum demand of digital exchanges is usually no more than that of the equivalent Strowger exchange, they have a flat load profile and are therefore consuming energy all the time, not, as in the case of a Strowger exchange, only when being used.

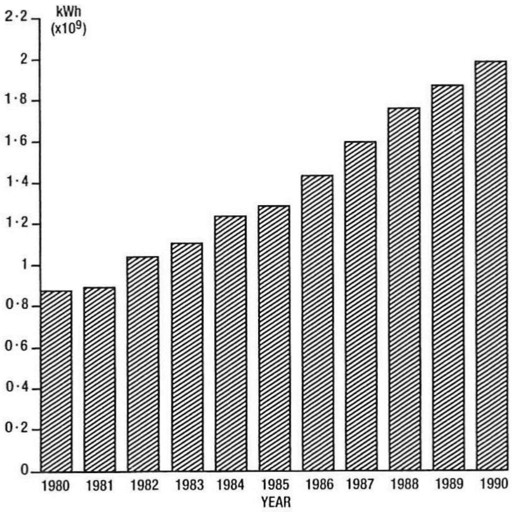


Figure 2—Electricity consumption

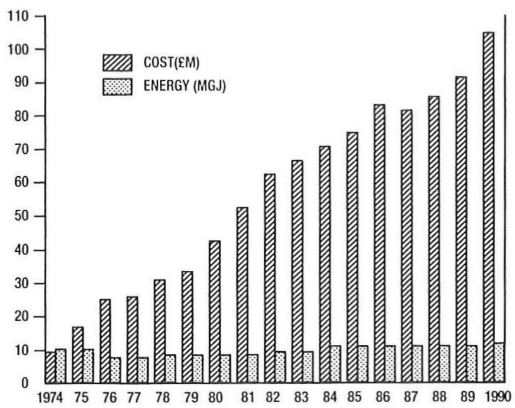


Figure 3 Expenditure and consumption on all fuels

The expenditure and consumption for all fuels from 1974 to 1990 is shown in Figure 3.

The BT energy bill is about 0·25% of the total for the UK, excluding fuel for transport in both cases.

Electricity Privatisation

Since the privatisation of the electricity supply industry, it has been possible to tender for the supply of electricity at sites where the maximum demand is more than 1 MW. Maximum demand is calculated as the average of the three highest monthly maximum demands in the preceding twelve months. Fifty seven BT buildings are supplied with electricity as the result of competitive tendering. It is estimated that the savings on the cost of electricity at these buildings is about £5M.

After 1 April 1994, it is intended that the lower limit for the supply of electricity by tender will be reduced to 100 kW, and after 1 April 1998 it is planned that the limit will be removed altogether.

ENERGY USE AND THE ENVIRONMENT

The World Environment

Twenty years ago there was concern that everyone would soon shiver to death because of the speed that the Earth's energy reserves were being used up. Artists impressions, showing London under about 5 m of snow, were produced. Today the fear is of the overheating of the planet resulting from the build up of man-made gases in the atmosphere. Pictures now show a new coastline with whole areas wiped out by the sea which has risen due to melting of the ice caps.

These apparently conflicting predictions have a common theme. It is that energy efficiency is not only of concern to the thrifty, but is the responsibility of us all. Carbon dioxide released by burning fossil fuels along with other man-made gases are thought likely to be raising the temperature of the Earth's atmosphere by trapping solar heat and creating conditions that cause a warming of the Earth. This warming has become known as *the greenhouse effect.*

The global average air temperature is higher than during the 1880s, at the start of the industrial revolution. The amount of carbon dioxide in the atmosphere has also increased during this period.

On present trends, carbon dioxide levels could reach double the pre-industrial level by the middle of the next century. It will be some years, however, before any greenhouse effect stands out clearly from random climatic variations.

Despite the lack of conclusive proof about the greenhouse effect, it would be foolish not to consider the possibility of global warming as a real threat. The time to take action to reduce it is now, not in the future when proof beyond all doubt is available. Even if the threat of global warming is found to be unfounded, putting resources into saving energy now will not be wasted and will still bring financial benefits to BT and any other organisation that manages its energy well.

Controlling BT's Effect on the Environment

There are proposals still in the discussion stage at the time of writing to ensure that BT matches any forthcoming legislation that relates to the reduction of carbon dioxide emissions. A Government White Paper, *This Common Inheritance*, published in September 1990[1] sets out UK policy. It states that 'The Government has announced that Britain is prepared if other countries take similar action to set itself the demanding target of returning emissions of carbon dioxide, the dominant greenhouse gas, to 1990 levels by 2005'.

In BT's operations, the most significant energy source responsible for carbon dioxide emission is electricity, and BT is currently facing a rise in electricity consumption due to the continuing modernisation programme for network equipment. Figure 4 shows the carbon dioxide emission resulting from BT's energy sources.

Electricity has the highest carbon dioxide emission to energy conversion factor of the energy sources used by BT. Carbon dioxide conversion factors are published by the Department of Energy[2]. These enable emissions to be calculated from the amount of energy used, the factors are:

- Electricity 231 kg/GJ
- Gas 55 kg/GJ
- Oil 84 kg/GJ
- Solid Fuel 92 kg/GJ

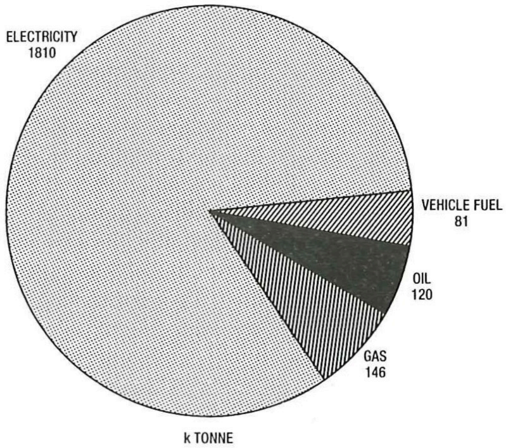


Figure 4 Carbon dioxide emission

Carbon dioxide conversion factors may change in the future. For example, if the mix between coal/gas/nuclear/renewable generation for electricity changes, the carbon dioxide emission per unit of electrical energy produced will alter.

It is estimated that BT's electricity consumption will peak in 1995 and, by the use of new technology in the network, will reduce to a level by the year 2005 such that BT will be able to meet the Government's proposals for carbon dioxide emission. Figure 5 shows the estimate of carbon dioxide emission from 1985 to 2005 resulting from BT's use of electricity for network equipment, electricity for non-network equipment and other fuels (of which only gas and oil are significant).

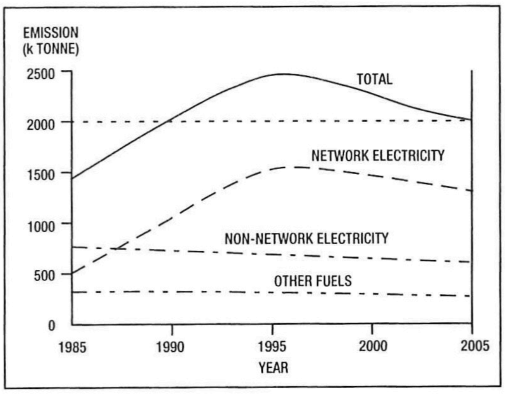


Figure 5—Estimate of carbon dioxide emission

The carbon dioxide emission for gas and oil are produced directly by BT, whilst the carbon dioxide emission for electricity is produced by the generating companies at the point of generation. BT's carbon dioxide emission of about two million tonnes annually is about 0·5% of the UK total.

Network electricity includes the electricity used by network supporting equipment such as cooling plant, the energy consumption of which will reduce as the network equipment energy consumption reduces, as described later. The small reductions in non-network electricity and the other fuels used will be achieved through energy management and changes in volume and technology.

NETWORK SYSTEMS

The electricity used by network equipment is now the major portion of BT's energy cost. Although electricity consumption is increasing as the network is modernised, a number of technology advances are starting to limit the increase. Forty percent of the energy consumption is used by the network, but because the cost of electricity per unit of energy is more than that of gas or oil, electricity used in the network is responsible for 55% of BT's energy expenditure. As the building stock and the number of BT people are not changing significantly, increases in energy consumption are the result of a greater consumption by the network.

The item with the greatest impact on energy consumption within a digital exchange is the route switch. In System X exchanges, this is known as the *digital switching subsystem* (DSS). Prior to 1990, System X exchanges used the DSS Mark 1 route switch. The power consumption of a maximum size (terminating 2048 pulse-code modulation (PCM) 2 Mbit/s systems) DSS Mark 1 is approximately 47 kW. Since early-1990, exchanges have been delivered with a DSS Mark 2 route switch. The design criteria for the DSS Mark 2 included a reduction in energy consumption. The use of large-scale integration and custom-designed integrated circuits enabled a complete redesign of the switch architecture. The result, in power consumption terms, is that the equivalent to the maximum size Mark 1 DSS, that is, terminating up to 2048 PCM systems, consumes approximately 8 kW.

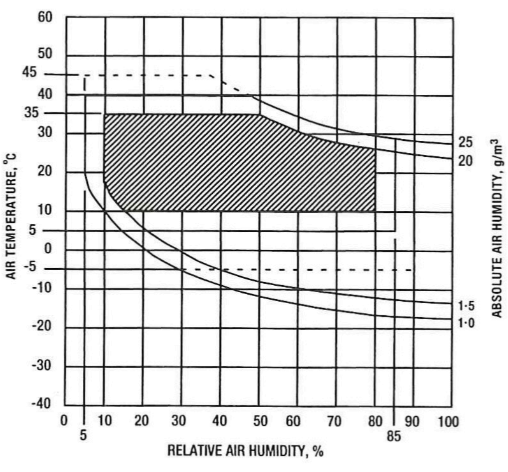
There is a similar story with transmission equipment as technology moves from transistor-transistor logic to complementary metal oxide semiconductor. In energy terms this means that a transmission shelf catering for one system and consuming 130 W has been replaced by a shelf catering for four systems and consuming 100 W.

COOLING SYSTEMS

BT Cooling Practice

Cooling systems for current digital switching and transmission equipment are able to take advantage of its relatively high tolerance to temperature and humidity. The climatogram in Figure 6 shows the temperature and humidity limits for equipment which is to be sited in conventional exchange apparatus rooms.

In theory at least, very little energy, if any, needs to be used to keep the room environment within the limits shown. The low temperature limit of 5°C will normally be met by the heat dissipation of the equipment itself. The upper limit of 40°C can be met by the use of mechanical ventilation alone making refrigeration plant unnecessary. It is fortunate that in the UK the humidity within an equipped building will stay naturally within limits, therefore avoiding the need for energy consuming humidification and dehumidification plant.



- - - - - - - - Exceptional climatic limits

———— Normal climatic limits
Values outside these limits have a probability of occurence of less than 1%

Values outside this field have a probability of occurence of less than 10% (see IEC 721-3-0 clause 4).

Figure 6—Climatogram for Class 3.1 temperature-controlled locations

In practice, attended buildings are held at a nominal 24°C in order to provide an acceptable environment for the people who install and maintain the equipment during its useful life. This necessitates the installation of refrigeration plant to take over from mechanical ventilation during the 20% of the year when outside air temperatures are too high to provide the required amount of cooling. Heating systems are not fitted to most attended exchanges.

Unattended buildings do not have the same restrictions and they enable BT to optimise energy savings by allowing the temperature to drift towards the upper limit of 40°C during very hot summer days. These sites rely on mechanical ventilation and so refrigeration plant is not provided. Similarly, during the winter months, the temperature is allowed to fall towards the lower limit of 5°C and heating, although provided, is only called upon in the severest of weathers.

As digital equipment becomes established and the need for people in attendance at them becomes less, there will be further opportunities for reducing the cooling energy bill. It will be possible to allow higher room temperatures during the summer period, thus reducing the time that refrigeration plant is running.

Alternative Cooling Methods

Schemes that use cooling water drawn from rivers or bore holes to be used directly or via a heat pump to provide air cooling for network equipment have been evaluated by BT. A number of unexpected costs have made these schemes risky to repeat. They all work well, but need constant attention because they are dealing with raw water with a dissolved or undissolved content that can vary considerably.

European Standards

The European Telecommunications Standards Institute (ETSI) is currently standardising many aspects of telecommunications, climatic environments being one of the first. Document ETS 300 019 includes climatograms defining various environments within which telecommunications equipment must work. The temperature and relative humidity limits for a normal equipment room are shown in Figure 6. Adoption of the ETSI standard by manufacturers has enabled BT to buy equipment from a wide variety of sources knowing that it will all work up to the high temperature limits shown. This continues to facilitate the adoption of standardised energy-efficient cooling

solutions. It has avoided the necessity for installing refrigeration plant in small unattended buildings and provides potential for reducing the amount of chilling done at larger sites, as the need for attendence becomes less.

Future Cooling Trends

There are potential stumbling blocks on the road to reduced energy consumption. The potential for increased equipment packing density brings with it the threat of higher heat density. This has already led some manufacturers to fit cooling fans on racks and, if pursued, this could ultimately force manufacturers to fit integral energy-consuming refrigeration plant within each rack.

Reduced energy consumption will come about by careful compromise between equipment packing density and room size so that energy-efficient cooling systems can continue to be used.

RECOVERY OF ENERGY

Since BT has a substantial quantity of high-dissipation equipment that needs cooling, the question of heat recovery often arises. A number of heat-recovery ideas have, in fact, been investigated with some getting as far as a trial. All have proved uneconomic when everything is taken into account. Normally, the low-grade heat that can be recovered is most plentiful when it is not required. There are also very few sites where accommodation that could use the heat is reasonably close to where the heat that could be recovered is dissipated. This, and BT's constantly changing use of buildings makes it unlikely that heat recovery will ever be used successfully.

A fairly extensive total energy scheme was commissioned during the 1970s where electricity was generated on site by using gas/oil engines and heat was recovered from both the exhaust and the water jacket. Some of the exhaust heat was converted, by using an absorption chiller, to chilled water and this was used in fan coil units to cool the network equipment. Initially, the scheme was economic, but changes in fuel prices and a steep rise in maintenance for the specialised equipment put the running costs above those of a conventional system where energy is purchased from the normal suppliers. The plant has recently been de-commissioned.

There are a number of low-grade heat recovery schemes designed to provide domestic hot water and, although these can be shown to payback in about five years, they use heat pumps that are more complicated and expensive than immersion heaters and need more maintenance. None have been spectacular in their performance.

CONTROL SYSTEMS

Optimum Start

Although a lot of energy used in a building can still be saved by human actions, control systems are gradually doing more of this work. *Optimum start* was an early idea that had considerable impact on the control of BT's heating systems during the 1970s.

Prior to the use of optimum-start systems, a building's heating was controlled by a time clock that was set to turn the heating on early enough to ensure the building had reached the required temperature in time for occupation. Since buildings are not normally occupied over weekends the heating was turned off, by using a 'day omission' facility on the time clock and the building allowed to cool down to a low temperature over two days. To achieve occupation temperature on Monday mornings, the time clock had to be set to turn the heating on early, and the same setting was used for all week even though there is normally residual heat in the building from the previous day. Some systems even used a night set-back method that kept the heating on, but at a lower temperature so that morning warm up was easier to achieve.

The optimum-start system monitors internal and external temperatures and is set according to the buildings thermal inertia so that it turns the heating on early enough to reach occupation temperature just in time. Fuel bills for a building were easily reduced by about 15% by installing optimum start, and installation costs could be recovered in less than a year for most installations. There was a noticeable reduction in the company's heating oil requirement after the optimum-start installation programme was completed for major buildings.

Building Management Systems

These early systems have now generally been superseded by computer-based building-management systems, which are able to provide many more facilities. A building-management system can monitor all functions in a building and react appropriately. Advanced systems incorporate expert systems and learning features.

In a building-management system, information is gathered by means of sensors for parameters such as temperature, pressure, flow rates, electricity and gas consumption. Programmed control actions are transmitted to various actuators for switches, valves, dampers etc. Information can be displayed on a computer screen or dumped to a printer. Temperature set points, timers, boiler controls etc. can be modified by using the computer keyboard. Control is achieved either by means of a central processing unit where information is stored, manipulated and analysed centrally or by means of distributed intelligent outstations, each of which can control a building or part of a site with a full-range of control facilities. Distributed outstations can communicate with each other by means of data links.

Since the introduction of computer-based building-management systems, energy costs have continued to increase while all the time the cost of computing power has been decreasing. A growth in the number of building-management systems in BT is therefore inevitable.

The energy-management value of a building-management system rests with its ability to control effectively plant and services, particularly at large and complex sites. Typical information obtained would be reports on space temperatures, plant and alarm conditions, and energy consumption. This is all information that is very useful to an energy manager for the analysis of energy consumption trends which would be difficult to obtain by any other means. Remote sites can be monitored and controlled without the need for visits, thus allowing more effective use of manpower.

Lighting Control Systems

Lighting is perhaps the most abused energy-consuming system, and although BT uses many lighting-control systems in its buildings, it is still very much under local human control. Considerable savings have been achieved by installing special lighting-control systems in apparatus rooms.

Gangway lighting can be controlled by time-delay switches or presence detectors, some of which have been specially developed for BT. The expenditure on electricity for rack lighting is more than £3M, and large savings can be made by using lighting controllers either based on timers or movement detectors. Typical energy savings are shown in Figure 7.

Movement detectors use ultrasonic or passive infra-red detection methods. The ultrasonic detectors transmit ultrasonic waves at a frequency of typically 40 kHz and use the Doppler effect to detect a presence. Passive infra-red detectors work by detecting the infra-red energy emitted by a person in the sensitive zone.

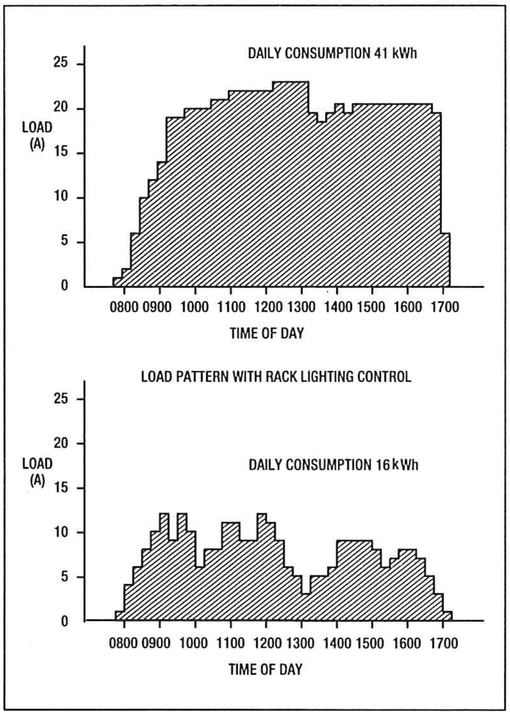


Figure 7—Rack lighting control

OTHER AREAS OF ENERGY USE

Computing

Approximately 10% of BT's electricity is used by mainframe and personal computing activities. There was a rapid increase in mainframe computer sites and personal computers during the 1980s. Now, more effective computing systems using new technology are leading to a reduction in the number of mainframe sites and the introduction of low-energy-consumption personal computers to undertake some of the work that was once done by mainframe computers is reducing the use of energy. This has had the effect of curbing the rapid rise of energy consumption in this area.

There are two areas where significant energy saving can be made in BT's computing activities:

(*a*) more efficient air-conditioning plant for mainframe computers, and

(*b*) improved operating procedures by users of personal computers.

Over the past five years, higher-efficiency cooling systems have been developed for use at large sites, such as mainframe computer centres. Large refrigeration machinery was, however, notoriously inefficient on part load, an operating condition quite common at computer centres outside the peak summer conditions. Savings of 30% to 50% have been achieved by the use of modern variable-capacity refrigeration plant that is able to operate efficiently over its normal load range.

'Switch off when not required' is a simple often repeated energy saving message that can now apply to most of the personal computing equipment and other electronic office equipment such as terminals, photocopiers etc. At one time, the reliability of this equipment was compromised by switching on and off, and it was common practice to leave some of this equipment powered up continuously. Overall, it has been estimated that if everybody complied with the 'switch off when not required' slogan for office equipment, a 30% saving would be achieved in this area.

Catering

Energy is a real cost which has to be passed on to the restaurant customer. According to investigations, commercial caterers use eight times as much energy as the practical minimum[3]. To achieve this practical minimum would, however, need perfect working practices and a kitchen designed from the outset for minimum energy use.

Typically, the energy cost per meal in a BT restaurant is 12p, and with 14 million main meals served annually, a 20% energy saving represents £336 000 in total, or 2·4p per meal. This saving is, on average, more than £6 per year for each regular customer served one meal per day.

CONCLUSIONS

Everybody who works in a BT building should know who is responsible for energy management in that building so that they can contribute directly towards saving energy. The BT energy bill is about £500 per capita of which about £200 is people controllable, such as heating, lighting and office equipment. Closing doors and windows, turning off lighting and office equipment when not required, and not wasting hot water, all quite modest actions, can save considerable sums of money and contribute towards a better environment.

ACKNOWLEDGEMENTS

Energy is a wide-ranging subject that encroaches on all people in one way or another from equipment and plant designers to someone sitting at a desk with a light switch to control. The authors would like to thank all the BT energy users who helped with the preparation of this article and in particular Tony Grainger, WN System Properties and Peter Kiff, WN Power & BES Technology.

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2 Energy Management. *Journal of the Department of Energy*, Nov./Dec. 1989.

3 LAWSON, F. R. Energy Use in the Catering Industry of Great Britain. Energy Efficiency Report No. G/44/84, 1983.

Biographies

Geoff Clark joined BT in 1969 from the Electrical Research Association where he worked on high-voltage transmission. During this period, he served a student apprenticeship and gained an external degree from London University. All his time at BT has been spent on many aspects of power and building engineering services work. He took over energy management responsibilities in 1985. He is a Chartered Engineer and a member of the Chartered Institution of Building Services Engineers.

Alan Bealing completed a drawing office apprenticeship at GEC at its switchgear design and manufacturing plant. He later became a draughtsman and technical writer/editor. He joined the Post Office in 1970 to work in the PHQ postal mechanisation drawing office and after two years moved to the THQ drawing office information bureau. In 1974, still with THQ, he joined Power Division where, after being involved with both AC and DC power plant, he became National Energy Manager in 1987. He is a Graduate Member of the Institution of Mechanical Engineers.

Keeping Account of BT's Energy Use by Means of a Personal Computer

A. C. BEALING†, and P. K. MARTIN*

The current emphasis on energy management makes it very important to know where energy is used and how much it costs. In addition, using a computer to assist with the adjudication of electricity tenders ensures that the maximum advantage is taken of this new opportunity resulting from the Electricity Act, 1989.

INTRODUCTION

Without the use of a computer and suitable software, keeping check of the energy consumption of more than one building can prove difficult. BT, with its multiple sites, would suffer under a huge deluge of paperwork and site information. The task of simple monitoring for overspend or energy saving would be difficult, and targeting by accurately adjusting to variables such as external temperature, hours of occupancy and changing equipment load might prove too difficult to even consider.

Fortunately, the advent of the personal computer has changed all this. The office personal computer with its software can be used as the energy manager's 'eyes and ears'. Overspending buildings can quickly be highlighted, and savings can be accrued and logged accurately.

The computer enables a wide range of information and data to be stored on disc. The results from an analysis provide the energy manager with performance reports for closely monitoring the energy use at each site.

At the 1987 BT energy managers' conference, it was decided to investigate what monitoring and targeting systems were available so that a standard system for use by Districts could be recommended.

A working party comprising five Districts was set up to undertake investigations into monitoring and targeting and to establish which personal-computer-based system would best meet the needs of BT. Five different systems were investigated and preliminary demonstrations were given. Three of these systems were discarded because they were either too underdeveloped or because they were not flexible enough for BT's needs. Because of the size of BT, it was considered very important that the system chosen could be adapted to meet its specialised needs.

Two monitoring and targeting systems looked worthy of further investigation, and these were evaluated by the East of Scotland and Westward Districts.

As a result of these evaluations, the TEAM (Targeting Energy Auditing and Monitoring) system was adopted. This would provide BT with a system that could evolve in accordance with its requirements; there was also the possibility of special developments to meet future needs. A licence was agreed between the Energy Auditing Agency, who produce the system, and BT; this enabled Districts to obtain TEAM to a standard set of conditions.

Figure 1 shows the system layout and how the information may be input to a personal computer in various ways to obtain a variety of different outputs.

DATA ENTRY

Data may be entered into the TEAM system in the following ways:

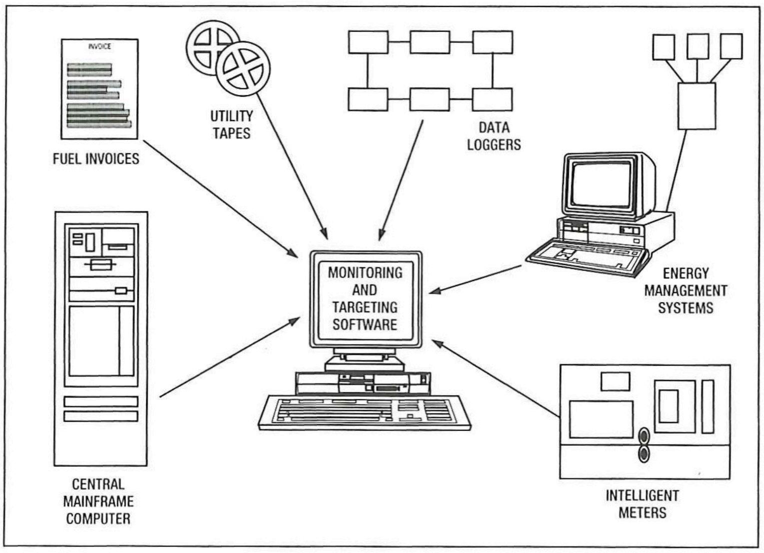
(*a*) manual input by means of a keyboard,
(*b*) download from magnetic tapes or discs supplied by the utility companies, or
(*c*) direct from energy-management systems.

DATABASE

Information Held on the Database

One of the most important aspects of a computer-based monitoring system is the database.

Figure 1
TEAM system layout



† BT Worldwide Networks
* Energy Auditing Agency Ltd

Subsequent analysis is only as good as the data supplied, so it is important to establish satisfactory procedures for obtaining and entering data. An energy manager's database includes the following information:

- Property details: building name, address, site contact, telephone number, account number, utility board.
- Fuel data: delivery or meter reading data, energy usage, cost.
- Further information if the energy manager wishes: floor area, heated volume, exposure, hours of occupancy, holidays, shiftwork.

Having created a basic file of information on energy use and related details, the computer may be used to log other information such as boiler and hot water plant, controls, building fabric, maintenance records and schematic diagrams of the plant layout. Figures 2 and 3 show how site details may be printed or displayed on the screen as a plant list and a schematic diagram.

Use of the Database

The energy consumption and expenditure information held on the database helps to ensure that investment decisions that are dependant on energy use are made objectively and that energy consumption targets are achieved.

On a more day-to-day level, when a report is generated by the computer showing a building overspending to target and in need of attention, the energy manager can produce a computer printout of the plant details if these have been entered into the database. The maintenance

Figure 2
Site details: plant list

```
                     PLANT INVENTORY
A. Heating Boilers (No.2)          :  Beeston Robin Hood Major
                                      Selectos JSS4 Pressure
                                      Jet Oil Burners
B. HWS Boilers (No.2)              :  Beeston Robin Hood RS02
                                      Selectos JSS2 Pressure
                                      Jet Oil Burners
C. HWS Cylinders (No.2)            :  1600 Litres Capacity
D. Boiler Pumps (No.2)
E. Heating Pumps                   :  Turney Turbine
                                      Nos. 86089 & 86090
F. HWS Primary Pumps               :  Grundfos
G. HWS Secondary Pumps             :  Turney Turbine No. 79439
H. Heating Control                 :  Langis & Gyr 3" Three
                                      Way Mixing Valve
 . HWS Control (No.2)              :  Landis & Gyr 1.1/2"
                                      3 way Diverting Valve
K. Optimum Start Control           :  Landis & Gyr OSC8
   (Heating Boilers)
L. Inside sensor
M. Outside Sensor (No.2)
N. Outside Compensator             : Landis & Gyr RVL41.00

Control: The Heating boilers are on optimum start control
         with an outside compensator varying the flow
         temperature to the system.  The HWS boilers are on
         time switch control and the HWS cylinders have
         thermostatic control.
```

Boiler	A1	A2	B1	B2
Control Stat	80C	80C	80C	80C
Flue Temperature	400C	380C	540C	440C
CO2 %	12	9.5	6	5
Excess Air %	25	57	140+	150+
Flue Gas Loss %	26	29	55	50

	TEXACO
OIL PRICE	30.0

1-3	Normal Day & Time	Monday - Friday Omit Saturday & Sunday
4	Normal 'On'	09.00
5	Normal "Off"	16.00
6	Normal Search	4 hours
7	Early Search	6 hours
8	Frost Level	10C
9	Normal Building Temp.	19C
10	Min. Design Outside temp.	-1C
11	Alternative "Off"	17.00
12	Extension Time	04.30

manager can then be provided with information by the energy manager to help his team diagnose the problem and take the correct spares to site on the first visit.

WEATHER ADJUSTMENTS

Comparing a building's present energy use and costs to previous years does not provide a true picture. Adjustments are necessary to make provision for variables such as:

- external air temperature,
- changes in the telecommunications equipment load, and
- building occupancy.

Each of these variables may effect the energy use and it is therefore necessary to establish the significance of each.

External air temperatures are adjusted by the weather-adjustment factor known as *degree days*; these enable an allowance for temperature variations from year to year to be made when comparing the efficiency and fuel consumption of heating plant.

The generally-accepted definition of a degree day is the daily difference in degrees centigrade between a base temperature of 15·5°C and the 24 hour mean outside temperature, when this is below the base temperature. When the 24 hour mean outside temperature is above the base temperature, the degree day figure is zero. The monthly figure is obtained by adding together all the daily figures for the month in question. Degree-day figures for calendar months in the current and previous years and the monthly 20 year average figures are published and available to energy managers.

By dividing the 20 year average figure for the months in question by the current figure for those same months, a correction factor is obtained.

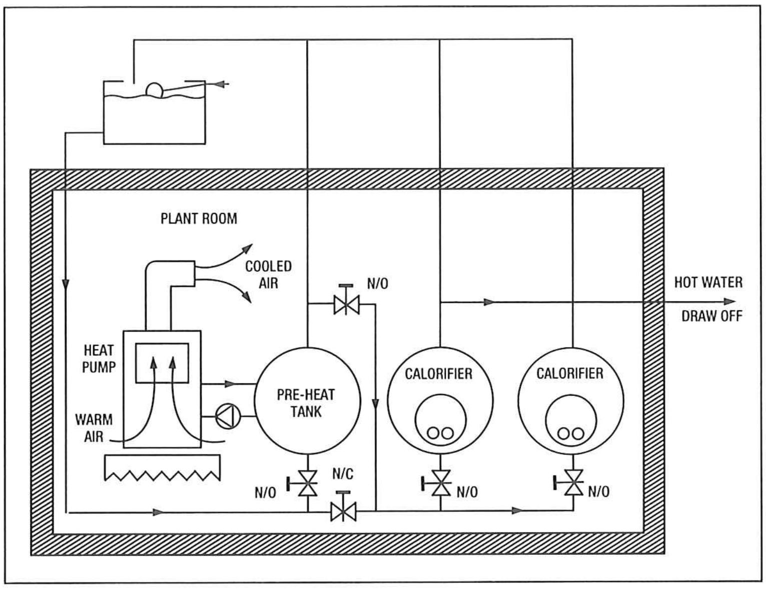
Adjusting the heating-fuel consumption to outside temperatures is also a useful tool for the energy manager when asked to justify a capital investment scheme that at first glance does not appear to be paying back because more energy is being supplied to the building than at the same month during the previous year. Analysing fuel usage on the computer enables paybacks to be verified in cases like this where the extra energy used results from colder weather than that of the previous year.

OUTPUT PRESENTATIONS

Energy Consumption Movements and Trends

Where several sites are to be compared, league tables are useful for displaying highest through to lowest consumers. For sites of a similar type (for example, standard buildings with similar exchange equipment), it may be possible to compare them directly. Selective searches can be made to identify these sites. If a direct comparison is not possible, weather adjustment factors have to be used. Figure 4 shows the changes of electricity consumption at selected sites over one year. From this it can be seen that the best and worst sites are easily identified. The annual electricity consumption in kilowatt hours and changes in kilowatt hours and percentages are shown compared with the previous year.

Calculation of monthly figures allows a month-on-month comparison of movements and trends. There are many methods of displaying the analysis, and Figure 5 shows a three dimensional histogram of the gas usage at a particular site for a year July to June. A comparison of one month's data with the same month in the previous year can provide a useful indication of movement and it allows increases in consumption to be quickly identified.



N/C: normally closed   N/O: normally open

Figure 3
Site details: plant layout

Figure 4
League table of movement on previous year

League table of movement on previous year

Details	Range : Apr 90 to Mar 91	kWh	Move	Move %
SELBORNE	[162]	9899	3796	62
ALDERSHOT	[174]	30281	7633	34
SMITHBROOK TRS	[171]	21644	3798	21
SLOUGH TEC	[168]	165404	16004	11
SHERE ATE	[163]	46999	3691	9
SILCHESTER ATE	[165]	52546	4098	8
SEALE TRS	[161]	3157	191	6
TELECOM HOUSE, ALDERSHOT	[180]	1173433	-23936	-2
TADLEY ATE	[177]	236297	-9484	-4
SPENCERS WOOD ATE	[173]	116301	-9891	-8
SONNING RADIO STATION	[172]	27958	-9060	-24
Slough RCU	[170]	34001	-14890	-30
SREATLEY TRS	[175]	23391	-14092	-38
Total for entire league table		1941310	-42144	-2

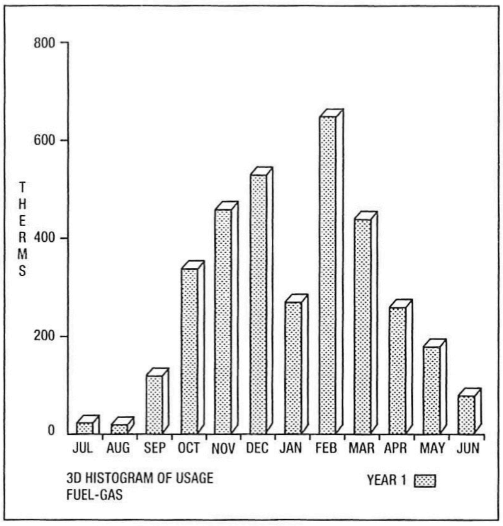


Figure 5—Histogram of fuel usage

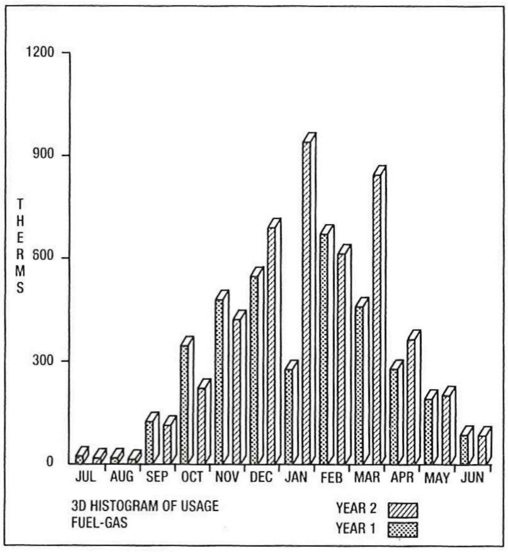


Figure 6—Comparison of fuel usage

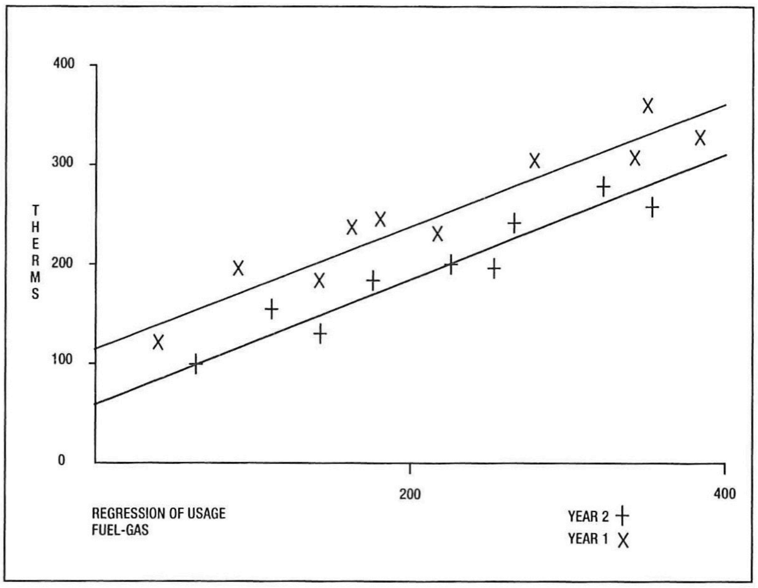


Figure 7—Regression analysis

Figure 6 shows two years consumption on the same histogram. Movements over a number of years may be monitored by comparison with a base year. Any 12 month period can be selected for a base year although it is usually best to use a financial year before any energy management measures were implemented.

Dependence on a Particular Factor

Changes in the telecommunications equipment load are calculated by using power-consumption information obtained from equipment planners.

Building occupancy can be monitored by ensuring that any change of use of the building is recorded.

The usual method of establishing dependency on a particular factor is by common sense and to plot energy usage against the factor over a 12 month period to obtain the 'line of best fit' through the points. A significant slope on the line indicates a relationship. If no factor is found to be significant or there is a large amount of scatter about the line, adjustment should not be attempted. In the latter case, more accurate data may be required.

Base Load

Figure 7 shows a regression analysis where the boilers are also used for the generation of domestic hot water throughout the year. Note the 'base load' offset at the intercept with the y axis. This base load is not weather dependent and has to be subtracted during adjustment. Only the heating load (signified by the gradient) need be adjusted to the weather factor. It is important to separate the variable portion of the fuel's usage away from the non-variable base load portion.

The base load can be seen to have reduced, although the heating load remains the same. In this instance the base load had been reduced due to energy saving measures implemented by the energy manager.

CUMULATIVE SUM DEVIATION (CUSUM)

An additional method of analysis uses the CUSUM technique to show how much energy or cost has been saved from a given date. The user specifies when an energy saving measure has been implemented and the computer software calculates the total saving or overspend to the present date.

This is achieved by specifying a base period within the database range which acts as a standard by which savings are judged. This typically might be a period of one year prior to the implementation of energy saving measures.

Data may be analysed month by month and a cumulative saving (CUSUM) derived. The result may be shown in report or graphical format. Figure 8 is a graph showing the cumulative savings of gas following an energy saving measure introduced in the last quarter of 1987.

FORWARD FORECASTING AND TARGETING

Forecast statistics are derived by using regression analysis and estimates of any adjustment factors used during the forecast period. For example, by using heating fuel data adjusted to 20 year average degree day figures, (the average weather data over the last 20 years) estimates of future usage can be predicted over a financial year. Weather predictions of this nature could normally be unreliable on a month-to-month basis, but over a year the estimates can provide a good indication of future energy consumption. This method can also be useful for budgeting and for cash-flow predictions.

A target consumption can be set for a property by using these normalised performance indicators, calculated design consumption, predicted energy savings from, say, insulation, or a simple percentage reduction. The performance compared to the set target can be monitored on the computer.

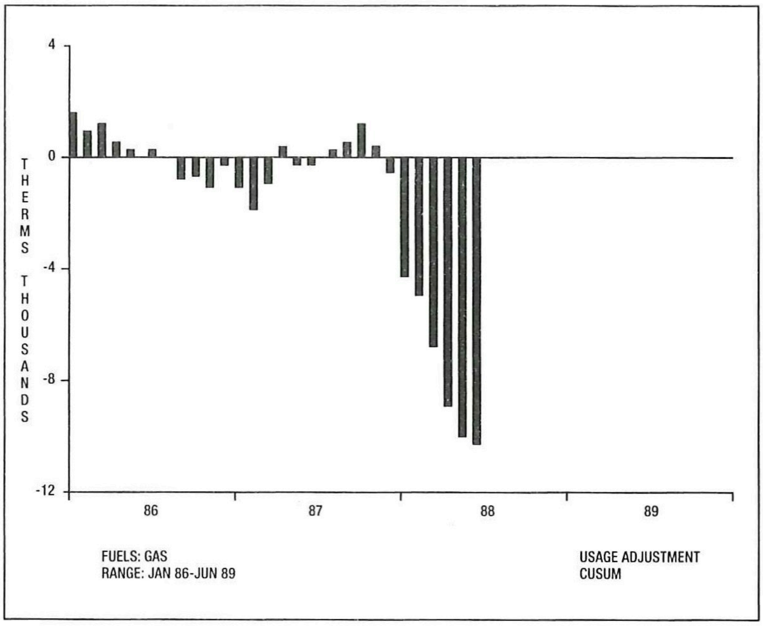


Figure 8
Cumulative savings display

CASE STUDIES

Faulty Control

An energy manager, without visiting the site, noticed from his computer that a particular building had a rising energy consumption trend. When the manager responsible for the building was contacted, the energy manager got the not surprising reply that as he had not visited the site how did he know that there was anything wrong? A check was however carried out and all thermostats and boiler controls were found to be in order, but the rising trend continued. It was then decided to undertake a round-the-clock check on the building, by means of recording instruments, and it was discovered that the 19°C internal temperature was being maintained at night when the building was unoccupied. Further investigation revealed that a button near the doorkeepers desk intended to override the normal timer settings and provide a further 2 hours of heating in the event of late working had become stuck in the ON position.

During the few months after the rising consumption had been noticed and before the sticking button found, the unnecessary energy used had cost around £20 000. Without a monitoring and targeting package and a vigilant energy manager, the button may well have remained stuck and so continued to waste energy.

Inaccurate Meter Reading

A search of high-energy-use buildings on a district TEAM database revealed that a repeater station that had had its equipment removed was among the list of high energy users. The only electrical loads were a compressor and a few lights, a consumption of just a few kilowatt hours per month. Further analysis revealed that a number of meter readings had been estimated. It was discovered that the electricity board had assumed that the meter readings had gone round the clock three times, to give approximately the previous consumption, rather than the consumption being reduced. A check meter was installed for two weeks by the electricity board and as a result of this they credited BT with £17 000 at the time of the next invoice.

In the District where this occurred prior to the installation of energy monitoring software, electricity invoices were paid by the accounts department and the energy manager was not able to inspect them closely.

A monitoring-and-targeting system makes it much more likely that errors of this sort are noticed.

ELECTRICITY TARIFFS

A tariff module for TEAM is available for all of the electricity companies supplying BT. Any 12 month period within the database may be analysed by the package for both quarterly and monthly billing periods. Graphs show comparisons over several years of all elements within the fuel bill (for example, day units, night/off-peak units, maximum demand, fixed costs and load factor). 'Break-even' points may be determined to show cost equality between two tariffs, such as the percentage night usage required before a change to a night-time tariff is appropriate.

Each site may be analysed individually, but to save time a summary table showing sites most likely to be on the wrong tariffs can highlight problems more quickly.

The simplest method of identifying incorrect tariffs is to display a league table of cost over usage for all sites on the same tariff. Sites at the top of the list and having a high cost per kWh are then analysed in more detail.

The tariff module may also be used to detect when the maximum demand is significantly below the availability level that the electricity supply company is charging for. In this case, a saving may be made by reducing the availability in the forthcoming year.

Ref	Name	Account	Tariff		p/kWh	Max MD	Max Serv	% Night
24	ANOTHER TE	0000432515406	WEBQ	3	5.57	0	0	64.70
23	WHICH TE	0001457304125	WEBQ	2	4.42	0	0	68.58
21	WHERE TE	0009020253003	WEBM	1	4.31	145	150	31.22
26	FICTION TE	0099707015790	MNWM	3	4.28	62	150	26.23
25	OLD TE	0099797029370	MNWM	2	4.27	62	100	5.91
22	NO TE	0009028604706	WEBM	1	3.44	189	200	41.29

Figure 9
Tariff database analysis

Figure 9 shows a table from the tariff database which indicates the best tariffs for a number of sites that have been analysed.

ELECTRICITY CONTRACT ADJUDICATION

The Electricity Act, 1989, has ended the 40 year monopoly for the supply of electricity. For sites of more than 1 MW maximum demand, it is now possible to place competitive tenders for the supply of electricity with the various competing electricity supply companies.

A tariff adjudication module has been developed to help with electricity supplies over 1 MW so that the best supply contract may be chosen to maximise cost savings.

Even a 1% cost saving at a site can result in the saving of thousands of pounds. The supply contract tariffs of National Power, PowerGen and the area electricity companies are usually complex in structure, therefore a like-for-like comparison cannot be made. The task of evaluating the most favourable supplier is therefore difficult without the assistance of a computer.

Comparisons can be made on computer by using historical billing information and a knowledge of the site electricity-use patterns. This ensures that BT is in a position of strength when negotiating contracts with the electricity suppliers.

Various contract tariffs are created and stored for quick access during comparisons. Information from the past twelve months is then used to provide a historical profile of electricity use.

As experience is gained with electricity contracts, load profiles will be obtained from building-management systems or directly from the electricity supply company meters. Experiments are taking place with these methods now. This will give a very accurate indication of when and how much electricity is used over the course of a day, a week or a month. The more accurate and comprehensive the information used, the more accurate the evaluation of the tender will be.

During the first tenders, all the necessary information was not always available. This meant that estimates of load profiles using the District energy manager's local knowledge had to be used. In these circumstances, the software uses interpolation techniques to build up a load profile.

'What if' routines are initiated when the various tariffs are overlaid on the site load profile. Many calculations are done by the software to determine the projected annual running cost under each contract. The various costs for different potential contracts are then displayed. These may then be transferred to a simple spreadsheet which shows at a glance the costs for all the different tariffs and all the sites. There were 43 sites and 14 possible suppliers when the last tender was adjudicated.

A wide variety of graphical and tabular displays are provided for viewing; these include cost, tariff and consumption details. Cost-sensitive periods of the day and year may also be displayed. Figure 10 shows how the day is displayed so that the most sensitive part of the day is shown, in this case between 16.00 and 18.30.

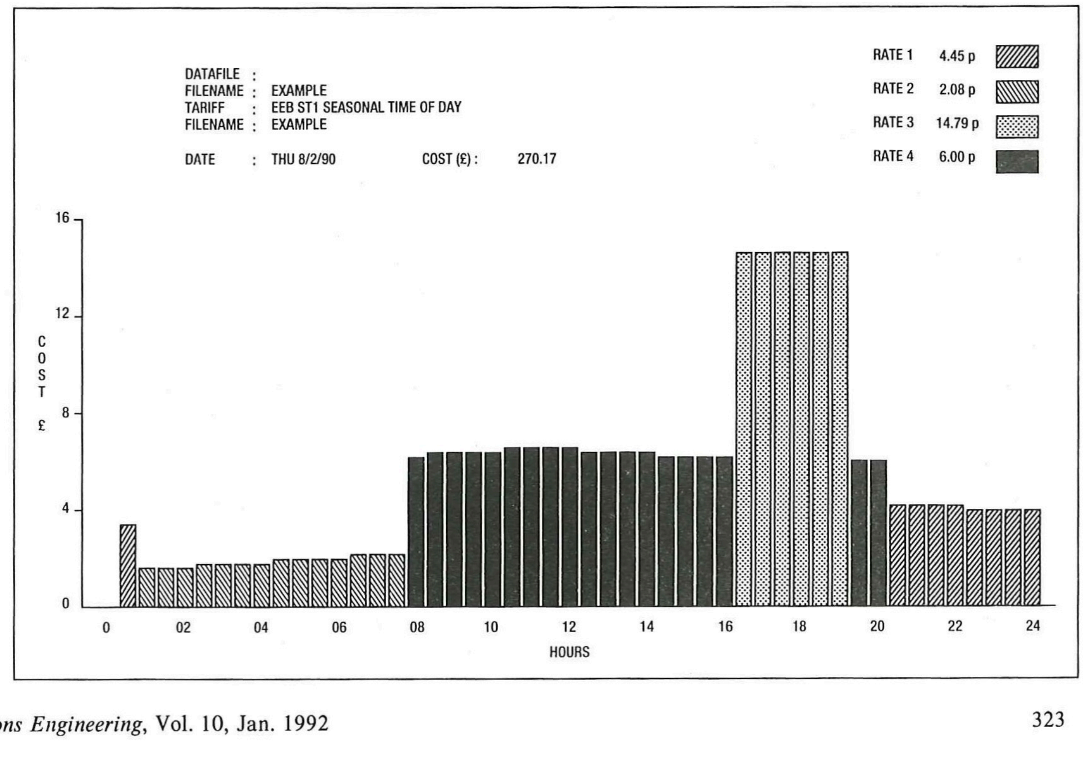


Figure 10
Display of cost-sensitive periods

Datafile :										
Tariff : EEB ST1 Seasonal Time of Day						Standing Charge £			17.60	
Filename : EXAMPLE						Availability kVA			300	
						Availability p/kVA			72.00	
Date : Apr 1989						Reactive p/kVA			.00	
Month	kWh	Cost(£)	MDkW	Factor	MDkVA	p/kVA	Cost(£)	kVAr	Cost(£)	Total(£)
Apr	111290	4291	227	1.000	227	.00	0	0	0	4524.42
May	117266	4512	226	1.000	226	.00	0	0	0	4745.39
Jun	108929	4192	217	1.000	217	.00	0	0	0	4425.64
Jul	98387	3792	193	1.000	193	.00	0	0	0	4025.76
Aug	92873	3573	179	1.000	179	.00	0	0	0	3806.96
Sep	96377	3712	194	1.000	194	.00	0	0	0	3945.97
Oct	109299	4209	213	1.000	213	.00	0	0	0	4442.54
Nov	117277	6400	234	1.000	234	247.00	578	0	0	7211.02
Dec	118277	8906	233	1.000	233	792.00	1842	0	0	10981.11
Jan	127278	9911	245	1.000	245	792.00	1940	0	0	12084.03
Feb	118282	6419	254	1.000	254	247.00	628	0	0	7280.95
Mar	119299	4594	232	1.000	232	.00	0	0	0	4827.68
										72301.48

Figure 11 Annual tariff estimate

Figure 11 shows an annual estimate for a particular tariff for comparison with other tariffs, the total annual cost for that particular tariff is shown to be £72 301.48.

ACCRUALS

An accruals module has been developed for BT. This enables the cost of energy to be accrued to any chosen date. Financial departments need this as utility invoices do not coincide with BT's accounting dates.

The most common need for an accrual calculation is when monthly accounts are needed. If an accrual is required one or two months after the last invoice, the programme estimates the expected energy use based on previous figures. This estimate may incorporate weather adjustment factors when heating fuels are being analysed.

THE ENVIRONMENT

The threat of global warming, environmental instability and the possible use of green or carbon taxes on fossil fuels has increased the need for energy efficiency. Energy management is now recognised as one of the easiest and most cost-effective ways of limiting or reducing carbon dioxide emissions.

To reduce greenhouse gas emissions, it is necessary to utilise these basic management techniques:

(*a*) understand what gases are emitted, where and in what quantities;

(*b*) formulate plans to reduce these through new practices or projects;

(*c*) implement energy saving measures and set reduction targets;

(*d*) monitor the success of the energy saving measures over time; and

(*e*) disseminate this information.

The easiest way of achieving these objectives is not by taking air samples, but by monitoring energy consumption and calculating the various emissions from the energy used. This of course is just the method used in energy monitoring and targeting methods.

Energy and environmental emission monitoring therefore go hand in hand. Every kilowatt hour of electricity, therm of gas, litre of oil and tonne of coal consumed contributes in some way to the greenhouse effect or atmospheric pollution either on site or at the power station where the electricity used is generated.

Published conversion information[1] states that for every unit of energy consumed, the following carbon dioxide emissions result:

- electricity: 231 kg of carbon dioxide per gigajoule of energy consumed;
- gas: 55 kg of carbon dioxide per gigajoule of energy consumed;
- oil: 84 kg of carbon dioxide per gigajoule of energy consumed; and
- solid fuel: 92 kg of carbon dioxide per gigajoule of energy consumed.

This enables a direct comparison of carbon dioxide to be made between different energy sources.

Using the more usual units for the different sources of energy results in the following carbon dioxide emissions:

- electricity: 0·83 kg of carbon dioxide per kilowatt hour;
- gas: 5·83 kg of carbon dioxide per therm;
- oil: 3·19 kg of carbon dioxide per litre; and
- solid fuel: 2576 kg of carbon dioxide per tonne.

Energy consumed in BT buildings is responsible for producing approximately two million tonnes of carbon dioxide annually. To control this BT people have to be encouraged, motivated and made aware of the benefits of saving energy, which may be displayed in environmental rather than energy terms.

A recent survey by the Department of the Environment[2] showed that 83% of people inter-

viewed were either very worried or quite worried about the depletion of the ozone layer, whereas 72% were very worried or worried about the warming of the atmosphere due to the greenhouse effect. This is a powerful body of opinion to mobilise.

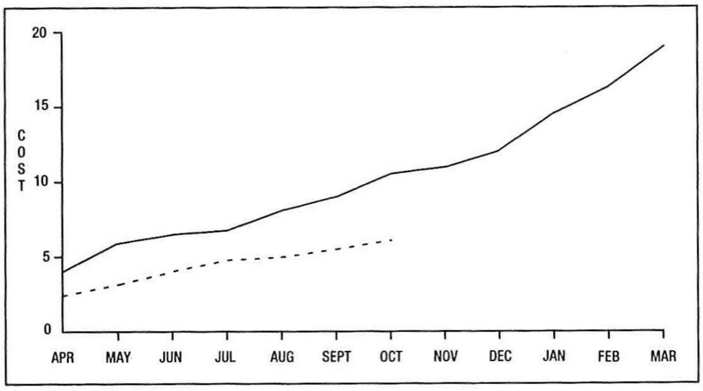
Some of the main reasons why an already overworked energy manager should take on the added responsibility of reducing greenhouse gas emissions are:

- it provides an opportunity to make a genuine contribution to a worrying condition,
- it is an excellent opportunity to reinforce the importance of energy efficiency to BT people, and
- such responsibilities enhance the perceived status of the energy manager, and this is not difficult to do if energy use is already monitored closely through an energy monitoring-and-targeting system.

With this in mind, the Energy Auditing Agency has developed a reporting module for BT's use. This makes possible the generation of graphical site-performance reports showing carbon dioxide emission trends with energy use and expenditure information for individual sites. These may be pinned to notice boards alongside a simple good housekeeping reminder. A2 size coloured posters have been produced with an energy-saving message to draw attention to the printouts on display. BT claims to be the first company in the world to display energy and emission information in this way. A reporting package printout for display in a BT building is shown in Figure 12.

Figure 12
Typical energy-saving message display

ENERGY AND ENVIRONMENTAL REPORT SHEET



Graph of this year against last year
Cumulative cost spend on energy

1988 ——
1989 - - -

FUEL	MONTHLY Sept 1989	MONTHLY Variance on Sept 88	YEAR TO DATE 1989	YEAR TO DATE Variance on 1988
Gas	325	-50	2292	-272
Electricity	279	+45	1654	-195
Oil	105	-22	892	-150
Water	121	-7	759	-77
TOTAL	875	-34	5597	-694

ENERGY SAVINGS FOR THIS YEAR	694 pounds

CO_2 EMISSION DECREASE	11.4 tonnes

CONCLUSION

The personal computer makes the energy manager's job easier by taking the hard work out of energy monitoring, alerting the manager to sites that need attention and accurately calculating savings that have been achieved.

The increased public awareness of the possibility of global warming has prompted companies such as BT to review their energy use and the resultant greenhouse gas emissions, with a view to reducing them. Fundamental to such programmes is the need for an information system that can log, analyse and report not only on energy use, but on carbon dioxide emissions as well.

The energy manager is in the best position to operate such a system. By seizing the opportunity, it allows him or her to repackage an old message and stimulate a greater awareness of the benefits of energy efficiency.

ACKNOWLEDGEMENTS

The authors would like to thank all the field energy managers who have assisted in the preparation of this article.

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Biographies

Alan Bealing completed a drawing office apprenticeship at GEC at its switchgear design and manufacturing plant, later becoming a draughtsman and technical writer/editor. He joined the Post Office, in 1970, to work in the PHQ postal mechanisation drawing office and after two years moved to the THQ drawing office information bureau. In 1974, still with THQ, he joined Power Division where after being involved with both AC and DC power plant, he became National Energy Manager in 1987. He is a Graduate Member of the Institution of Mechanical Engineers.

Paul Martin became a freelance energy consultant in 1980 after gaining an M.Sc. degree in applied energy at Cranfield Institute of Technology. Between 1983 and 1985, he worked as a partner at Energy Designs and Surveys which specialised in energy surveys of industrial and commercial sites. He became a founding director of Energy Auditing Agency Limited in 1985 and has played a large part in making the company one of the leading monitoring-and-targeting software houses in the British Isles.

Beyond the Second-Generation Mobile Radio Systems

S. T. S. CHIA†

The third-generation mobile radio system will be a multi-service, multi-environment system which will see a convergence of the second-generation cellular and cordless functions into an integral service entity. It will be supported by a range of multi-functional terminals providing reliable, ubiquitous, and good-quality services to customers. This article examines the issues affecting the service provision and the system capacity of the third-generation mobile system. In addition, it presents some of the salient features and technical possibilities for the radio network, the radio interface, and the supporting fixed network.

INTRODUCTION

Over the last decade, cellular mobile radio technology has opened up a world of new possibilities across Europe[1]. To many, the dream of being able to communicate by telephone while on the move has finally become an affordable reality. Indeed, in many parts of the world, cellular radio services have quickly, yet fundamentally, transformed the pattern of communications among the business communities. With the penetration rate predicted to grow by at least 40 times that of today[2], mobile communications are destined for more exciting developments over the next decade. In fact, long before the first-generation mobile radio systems attained maturity in the 1980s, the design of a number of second-generation digital mobile radio and cordless telecommunication systems (hereafter referred to as the *second-generation systems*) was already in progress. Moreover, the emergence of their corresponding multi-national standards in Europe (including the pan-European digital mobile system—GSM[3, 4], the second-generation cordless telephone—CT2[5], and the digital European cordless telecommunication system—DECT[6]) will forever change the boundaries of the telecommunications map. Selected characteristics of these second-generation systems are shown in Table 1.

Foresight is always the key to a lasting future. As we are living in a world where the demand for mobility is greater every day, a new third-generation mobile radio system, otherwise known as the *universal mobile telecommunication system*, will be required to meet customers' demand by the turn of the century. This third-generation mobile radio system (hereafter referred to as the *third-generation system*) will be a multi-environment, multi-service, multi-operator digital system[7, 8]. Above all, it must be able to satisfy three basic service criteria: reliability, universal coverage, and good voice quality.

With these service criteria, the commitments to future customers are rather simple. Specifically, the commitments will be:

- *Reliability*—whoever wishes to set-up a call will be able to complete it successfully;
- *Universal coverage*— whenever they wish to make a call, no matter whether it is in a rural area or inside an office building, a radio channel will be available for the call attempt;
- *Good voice quality*—as voice communications are expected to have by far the largest demand in the whole portfolio of service offerings, the voice quality must, therefore, be at least equivalent to the level of today's public switched telephone network.

However, it will eventually be the service providers who will be interfacing with the customers. In fact, these service providers simply supply value-added services to the customers by using the features and the functions provided by the third-generation system. Naturally, customers would

TABLE 1
Characteristics of Some European Second-Generation Mobile Communication Standards

Standard	CT2	DECT	GSM
Application	Cordless telephone	Cordless telephone	Cellular radio
Spectrum Allocation (MHz)	864–868	1880–1990	890–915 935–960
Modulation	Frequency shift keying	Gaussian minimum shift keying	Gaussian minimum shift keying
Carrier Spacing (kHz)	100	1728	200
Multiple Access	Frequency-division multiple access	Time-division multiple access	Time-division multiple access
Duplexing	Time-division duplex	Time-division duplex	Frequency-division duplex
Bit Rate (kbit/s)	72	1152	271
Speech Coder	ADPCM*	ADPCM*	LPC-RPE‡
Speech Coding Rate (kbit/s)	32	32	13 (full rate)

* ADPCM—Adaptive differential pulse-code modulation
‡ LPC-RPE—Linear predictive encoding with regular pulse excitation

† BT Development and Procurement

expect to see a continuity of service provisions from the second-generation system to the third-generation system. In other words, all the services available in the second-generation systems must also be available in the third-generation system and the service providers must be able to meet this demand. Furthermore, the third-generation system is expected to be capable of supporting new services which are beyond the capability of the second-generation systems. In fact, the ability of a service provider to provide a better range of services is very much dependent on the capability of the network as well as the resources made available by the network operator.

For the network operators, they need to provide the necessary network infrastructure in order to support the service providers and meet the demand of high user capacity. They are constrained by the finite spectrum allocation, the cost of the network infrastructure, and the requirements to interwork with other existing networks. To elaborate on this further, the very existence of any radio system depends on the availability of sufficient frequency spectrum. With a finite spectrum allocation, a high user capacity system could only be achieved by reusing the frequency allocation geographically. To meet the predicted mobile communication penetration of between 20% and 50% of the population[9], the cellular architecture for the current radio network has to be revised. Evidently, a change in the radio network architecture will have a major impact upon both the base station systems and the supporting fixed network. This impact will not only be in terms of the volume of signalling traffic, but also in terms of the interworking with other existing networks.

SERVICES

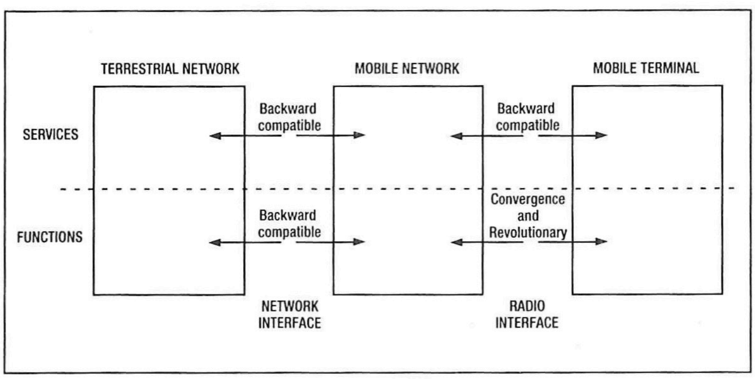
The design of any communication system is best driven by the services it is intended to support. For this reason, before the design of the third-generation system is undertaken, the services anticipated must be clearly defined. With the services defined, the traffic could then be estimated. However, predicting the future is never easy and, indeed, rarely accurate. Recognising this fact, at least a minimum set of services should be defined. Very briefly, this minimum service set requires the third-generation system to support a range of tele-services (including voice, video, and data) and bearer services. Moreover, the basic-rate integrated services digital network (ISDN) access must also be supported as a standard. In addition, higher bit-rate services in excess of 144 kbit/s may be supported, either within a specific environment, such as inside a customer premises network, or on the basis of bandwidth reservation in a public network. Other mobile-specific services such as navigation and road traffic informatics may also be supported.

In principle, the service concepts for the third-generation system could be expanded beyond those for its predecessors[10]. In the past, many system functions, such as location registration and handover, have been provided to the users as standard system features in order to maintain the system integrity. These features could, however, be offered to the customer as subscribable service options. For instance, in order to reduce the amount of signalling traffic due to location registrations, a number of roaming-capability options could be offered for subscriptions. At the bottom of the service range, a terminal will be able to support no location registration and will, therefore, be unable to receive any incoming call. Similarly, this service could further be graded according to the capability of provincial roaming, national roaming, and international roaming. On the same token, handover could also be offered as a service. For instance, mobile units subscribed to a lower class of service will have a lower reliability in handover. Indeed, the possibilities are endless.

As has been pointed out, the provision of services should be evolutionary. All the services supported by the second-generation systems must be supported by the third-generation system. This is important to ensure a continuity of service provision when customers migrate from the second-generation systems to the third-generation system. Evidently, the service set for the second-generation systems will only be a subset of that for the third-generation system. As illustrated in Figure 1, the implications could be far reaching. One of these is that the third-generation system must also be evolutionary in terms of fixed-network interworking. To be more precise, the third-generation system must be able, at least, to interconnect into all contemporary networks including the public switched telephone network and the ISDN.

In order to promote the range of services on offer, they must be matched by a range of terminals. Until the terminals are sufficiently cheap, the third-generation system will not be able to penetrate into the mass market. To accelerate the process, a new range of terminals should be offered to the customers. For the majority of the public, a simple voice terminal for occasional outgoing calls would satisfy their needs in most circumstances. A range of relatively inexpensive terminals should be available for this purpose. By contrast, customers with more requirements, such

Figure 1
Service and functions evolution for the third-generation mobile system



as those in the business sector, would need a much wider range of services. For these customers, a range of terminals with full service capabilities should be available for their selection. This will enable them to use the terminal as a cordless handset within an office environment or a low-power hand-held telephone in a city environment, or even as a higher-power mobile telephone in a suburban or a rural environment. Thus, an important underlying principle which has been illustrated here is that the third-generation mobile system must see a convergence of today's cordless and cellular functions and be supported by a range of flexible, multi-functional terminals.

SYSTEM CAPACITY

A main concern for any radio communication system is the user capacity. From a customer's perspective, this could be directly associated with the radio coverage and service reliability. When there is no radio coverage, there will be no capacity. Likewise, when a call set-up or a handover fails, the service reliability will be degraded. By contrast, from the network operators' point of view, user capacity is directly proportional to the infrastructure investment, and their ability to optimise a whole host of system parameters, such as frequency reuse planning. The issue of providing high user capacity thus deserves very careful deliberations.

With a finite spectrum allocation, user capacity could only be increased by adopting a higher-density frequency reuse pattern[11]. With conventional radio coverage techniques, which employ base station antennas mounted at prominent positions, the cell size will ultimately be limited by the radiowave propagation characteristics. The underlying reason is that when the base station antenna is above the sky-line of its neighbouring buildings, the radio coverage area within the close proximity of the base station is influenced by all the surrounding buildings and the local terrain features. As a result, the exact cell boundary is unpredictable. To circumvent the problem, we can introduce microcellular techniques by reducing the base station antenna height from the top of tall prominent buildings to the street-lamp elevations[12]. Their relative dimensions are shown in Figure 2. With this technique, the signal transmitted by the base station is confined within a small segment of a street. With the buildings acting as natural barriers to the proliferation of the signal energy, the radio channels in one street could be reused in a nearby street. As a result, there will potentially be a high increase in the user capacity.

In order to provide universal multi-environment radio coverage, a single cell size will not be sufficient. The cell size must be adapted to the specific environment in accordance with the traffic demand. Specifically, within a city centre, the cell size could be as small as one kilometre or less in radius in order to enable much denser frequency reuse. By contrast, in a rural area, the cell size could extend to beyond 20 km in radius. However, even within

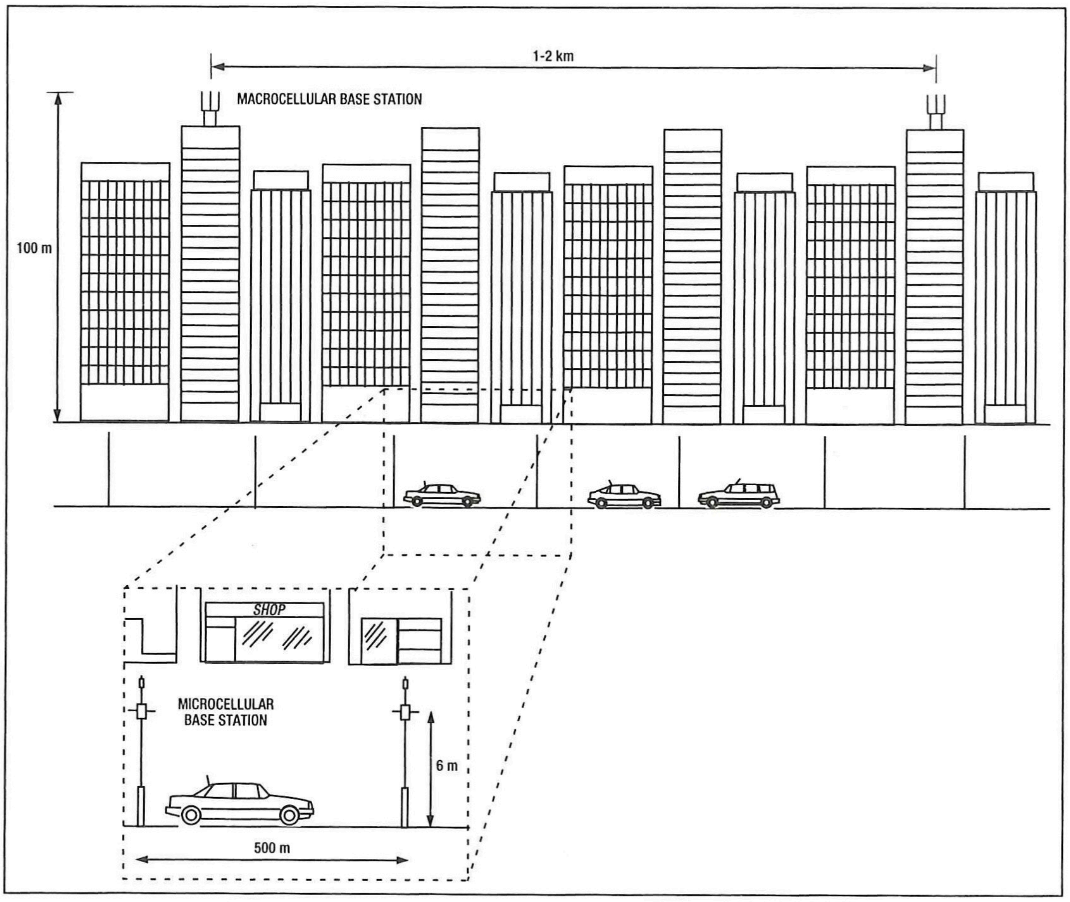
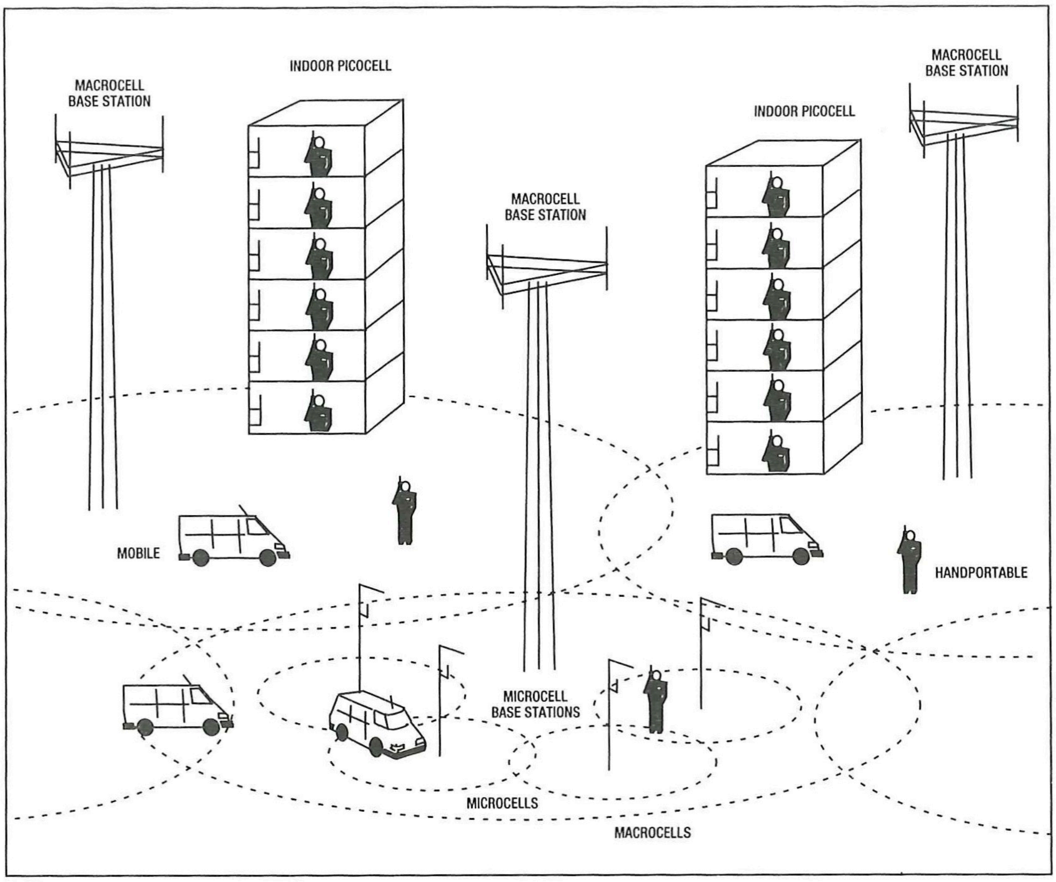


Figure 2
Relative dimensions of a macrocell and a microcell

Figure 3
A mixed cell system



a city centre, road traffic statistics have shown that most of the vehicles and pedestrians are concentrated in the main urban throughways and pedestrian precincts. Beyond those areas, the number of vehicles and pedestrians would be much lower. Moreover, microcells are ideal for providing strategic radio coverage to the area with high traffic density. Because of these reasons, contiguous deployment of microcell base stations on a wide-area or a national basis is not economically viable nor necessary. In order to provide continuous radio coverage across the whole area, it is proposed to use a mixed cell architecture where the microcells are overlaid with macrocells[13, 14], see Figure 3. The latter will provide wide-area radio coverage, while the former will provide strategic radio coverage. With these fundamental modifications in the cellular architecture, a number of new issues have to be addressed. Specifically, on the one hand, new challenges in the frequency planning and handover have been created, while on the other hand, new requirements for the design of the radio interface have been created. Both of these issues are non-trivial and some of their salient points will be addressed in the next two sections.

RADIO NETWORK

A radio network forms the kernel of a mobile radio system. With the ability to perform frequency reuse planning and handover, a network operator will be able optimise the user capacity and the system performance. The latter is frequently measured in terms of call blocking probability, handover failure probability, and interference probability. In order to understand the characteristics of the radio network for the third-generation system, extensive radiowave propagation measurement campaigns have been undertaken in the past[15–18]. This information has proved to be invaluable in providing insights on frequency reuse planning and handover procedure developments.

For a conventional cellular radio system, frequency reuse planning is normally performed by first dividing a service area into a mosaic of hexagonal regions[1]. Each hexagonal region will form a *cell* and will be associated with a base station. The spectrum allotment is divided over a repeating pattern of coverage area, so that no adjacent cells use the same frequency set. As the traffic demand grows, the cells could be subdivided or sectorised in order to provide a higher user capacity yet maintaining a sufficient carrier-to-interference ratio. Unfortunately, in reality, cells are never perfect in shapes and ideal base site locations are not always available. Thus, a sufficiently large safety margin for the radio link budget has to be implemented. This safety margin for the link budget has to be increased as the frequency reuse planning becomes less reliable. For small cell size, especially for microcells, the terrain features have dominant yet unpredictable effects. In this situation, a rigid frequency reuse

planning based on a large-scale survey map is not always feasible.

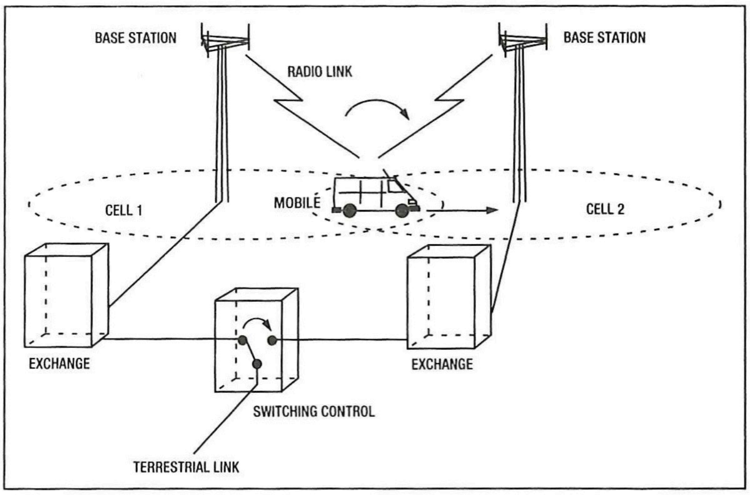
Over the years, several adaptive channel allocation schemes have been proposed[19–21]. These are generally known as *dynamic channel allocation*. In fact, a simple form of dynamic channel allocation is already used by CT2 and DECT. For the third-generation system, dynamic channel allocation will continue to be an important technique to circumvent the difficulty in frequency reuse planning in microcellular environments. With dynamic channel allocation, the whole frequency allotment is assigned to every base station in the system. The mobile units will search for a radio channel with relatively low interference to set-up a call or perform a handover. Because of this, dynamic channel allocation will allow flexibility in coping with incremental system growth in response to both traffic loading changes and varying capacity demand but without conscious frequency reuse planning. The response time could range from an instantaneous adaptation due to the traffic loading and interference fluctuation to a much longer-term adaptation in accordance to the changes in the terrain features and the user capacity. By regulating the threshold levels (for example, for call set-up and handover) for the adaptation process, a network operator could effectively control the frequency reuse distance and, hence, the performance of the entire network. In addition, by adopting a longer-term adaptation strategy, the base stations could be polarised into a quasi-stable frequency reuse pattern without actual frequency planning. In fact, this longer-term adaptation strategy will have a direct impact on the feasibility of implementing packet-radio-based multiple-access schemes in microcellular environments.

It must be noted that, in principle, dynamic channel allocation is more suitable for time- and frequency-division multiple-access schemes. However, packet radio multiple access is thought to be inherently more efficient in the provision of flexible bandwidth allocation. Specifically, in a time-division multiple-access system, flexible bandwidth allocation is accommodated by concatenating time-slots. The channel bandwidth is guaranteed, but the ability to maintain a connection is dependent on the reliability of the handover and the dynamic channel allocation process. By contrast, packet radio multiple access can efficiently utilise the bandwidth through statistical multiplexing[22]. However, the basic operation of packet switching relies on the constant availability of a reliable physical communication channel. In a cellular mobile radio environment, the channels are inherently unreliable. Because of this, a reliable physical communication channel could not always be guaranteed and lost packets would occur. To this end, quasi-reliability could only be provided by a regular (fixed) frequency reuse pattern. Although packet radio multiple access is capable of circumventing the interference impairment by contention and re-transmission, this may not be tolerable if the transmission is time critical (for example, interactive voice and video transmissions). Thus short-term dynamic channel allocation schemes would not be suitable for packet radio multiple access. Fortunately, the longer-term dynamic channel allocation schemes, as mentioned before, may be used to create a quasi-stable frequency reuse pattern even in microcellular environments. Thus packet radio multiple access remains a candidate multiple-access scheme for the third-generation system and could potentially be useful in less-time-critical data transmissions.

Thus it is always possible to implement some engineering solutions to circumvent the difficulties in frequency reuse planning. In fact, frequency reuse planning is even more complex in a mixed-cell system. It seems certain that because of the difficulties in the frequency reuse planning for microcells, dynamic channel-allocation schemes have to be introduced. However, for the macrocells, fixed channel allocation schemes remain the best option. In addition, as microcells and macrocells may co-exist in some locations, while only macrocells are deployed in others, the issue of a split-band allocation or a contiguous-band allocation to the macrocells and microcells has attracted considerable attention. Obviously, an accurate frequency reuse plan in a city centre containing independent business customer premises networks and the public networks will be difficult. Furthermore, neither uniform base station transmit power among the macrocells and the microcells nor time synchronisation could be expected from different network operators. A split frequency band assignment for the macrocells and the microcells is by far the simplest solution to prevent any conflict in interest between them. However, the disadvantage which needs to be considered is that the trunking efficiency would be reduced.

The integrity of a cellular radio system is dependent on the reliability of its handover process. Its principle is depicted in Figure 4. In a conventional cellular radio system, the frequency of handover per call is usually very low (once or twice per call). In the third-generation system, a

Figure 4
A schematic diagram showing the handover process

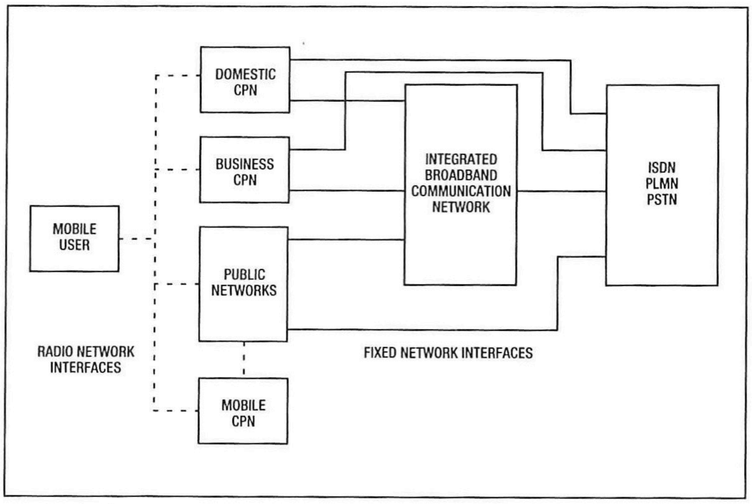


reduction in the cell size could result in an increase in the number of handovers by five times or more. It is well known that as the cell size is smaller, the decision and execution times for a handover need to be faster. In addition, from radiowave propagation measurements[12], it was noted that the signal level at a street corner could drop by 20 dB within a distance of 20 m. Evidently, it is difficult to maintain the handover reliability. To this end, several approaches have been proposed. For instance, with synchronised macrocell and microcell base stations, the macrocell could be used as a secondary option if a microcell-to-microcell handover fails. This concept could be further broadened to a combined forward-and-backward handover protocol[23]. A forward handover procedure establishes the handover signalling link via the target base station. Obviously, if the signalling link with the current base station fails for any reason, the call could still be re-established through the target base station. By contrast, a backward handover procedure relies entirely on the signalling link with the current base station. With this procedure, the advantage is that less network resources are required during the handover process. The combination of these two handover procedures to form a new handover protocol would allow utilisation of the advantages of both procedures and would, therefore, increase the reliability in the handover process.

THE RADIO INTERFACE

Linking the mobile units from the radio network into the fixed network will be the radio interface, commonly known as the *air interface*. For the third-generation system, the air interface should be capable of adapting to a wide range of environments, see Figure 5. In particular, the transition from one environment to another could either be distinct or continuous. For instance, when a customer travels from the centre of a city to its rural suburb, changes in the environment, and hence the radiowave propagation characteristics, would be rather gradual. By contrast, when a customer steps inside a customer premises network from a public network, the change in the environment would be more abrupt. Thus the air interface must be able to adapt continuously from one environment to another environment in some circumstances, while switching over abruptly in others. As the latter situation is a special case of the former, a continuously adaptive air interface is clearly preferred by customers. This is usually referred to as a *flexible air interface*.

Figure 5
Network environments for the third-generation mobile system



CPN: Customer premises network
PLMN: Public land mobile network
ISDN: Integrated services digital network
PSTN: Public switched telephone network

The flexibility and the efficiency of an air-interface comes in many dimensions. With the rapid development of digital communications, the capability of providing high-bit-rate transmission almost becomes a norm rather than an exception. For the third-generation system, the gross carrier bit rate which it could support depends on the permissible peak transmit power (for health and safety reasons) and the requirements in equalisation. As the signal bandwidth increases, the receiver noise floor increases correspondingly. The required peak transmit power is, therefore, dependent on both the signal bandwidth and link budget (the radiowave path loss characteristics and cell size). Simple calculations show that the peak transmit power for a carrier bit rate around 2 Mbit/s could amount to a few tens of watts if the cell radius exceeds 2 km. For this reason, high carrier bit rate must be restricted to be used in cells with small radii. Modifying the bit rate to suit the environment is possible and could be achieved in a number of approaches. The most direct approach is to switch the bandwidth of the transmission in accordance to the environment. Other approaches would be to change the symbol rate in a multi-level modulation scheme or to change the chip rate in a pseudo direct-sequence spread spectrum modulation scheme. The latter two techniques have direct implications on the choice of the modulation and the multiple access schemes and will be addressed further later.

In addition to the high peak transmit power hazard, a high carrier bit rate transmission can also cause inter-symbol interference in a digital radio link. This impairment is dependent on the time dispersion characteristics of the radio environment. The larger the delay spread, the more severe is the inter-symbol interference, the higher will be the error probability. This is usually compensated for by the introduction of an equaliser, which is effectively a digital filter which subtracts all the multipath components from the dominant desired digital signals. For a carrier bit rate of 2 Mbit/s transmitting in a typical macrocell environment with time dispersion of the order of few tens of micro-seconds, an equaliser with two to four taps would be required. However, the signal processing of this nature is unlikely to be a significant problem, especially for the timescale until the launch of the third-generation system.

Another dimension which could affect the efficiency of the air interface is the modulation scheme. The choice of the modulation scheme is

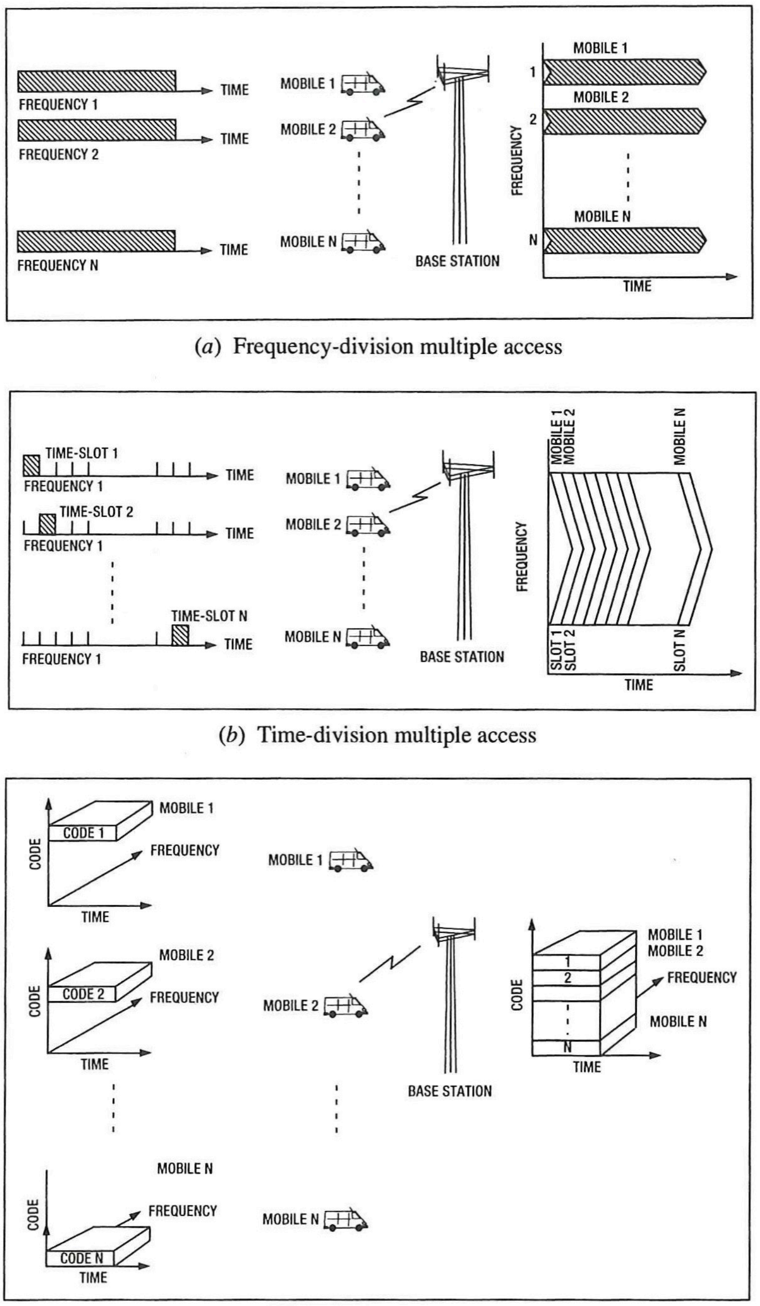
frequently based on its spectral efficiency and the complexity. Constant envelope modulation schemes such as Gaussian minimum shift keying (GMSK) have the advantage of being spectrally efficient yet remaining robust to both co-channel interference and adjacent channel interference. Typically GMSK with B_bT of 0·25 (where B_b is the 3 dB bandwidth of the pre-modulation filter and T is the bit period) has spectral efficiencies of about 1·4 bit/s/Hz[24]. Another choice is the non-constant envelope linear modulation schemes such as quadrature amplitude modulation (QAM). Computer simulations have shown that 4-level QAM has spectral efficiencies of about 1·5 bit/s/Hz but is less robust to co-channel interference and adjacent channel interference. The requirement of the use of a potentially power-hungry linear amplifier may not be a problem for low-power operations but would be a concern for high-power transmissions. To this end, a mixture of modulation schemes for the forward and the reverse link may be a possibility. However, multi-level QAM has the flexibility of carrier-bit-rate switching. When considering the complexity of the schemes, simple binary non-constant envelope modulation techniques can be employed which utilise the same non-coherent and coherent receiver architectures used for GMSK. The feasibility of such schemes depends on the levels of adjacent-channel interference that can be tolerated. For relatively large levels of adjacent-channel interference, non-constant envelope modulation would not yield any significant reductions in channel spacings, and, therefore, increase in system capacity[25]. In general, all modulation schemes and detection methods with narrow channel spacing requirements will lead to increases in co-channel protection margins. The decision will be dependent on the system requirement, the operating environment and the system capacity required.

The mobile radio channel is inherently hostile. Even with a relatively robust modulation scheme, digital transmissions over a mobile radio channel are still subject to impairment. While even more robust modulation schemes such as trellis-coded modulation are being developed, other means of channel protection have to be provided. For long-distance mobile radio communications, a range of channel protection techniques has to be implemented to ensure that the bit error probability is acceptable. To this end, techniques such as frame interleaving, slow frequency hopping, antenna diversity, and channel coding are frequently employed together. However, in the GSM system, the one-way transmission delay over the air interface, owing to speech coding and channel protection, is of the order of 90 ms. Severe echo problems would arise and echo cancellers may have to be implemented in tandem. All these could potentially lead to subjective impairment in the speech quality which would be unacceptable to the customers of the third-generation system. For this reason, the end delay for the third-generation mobile system must be reduced to the order of 20 to 30 ms, depending on technology[26]. Ways of achieving this could be assisted by

(*a*) reducing the delay in the speech codec,
(*b*) reducing the interleaving depth, and
(*c*) improving on the techniques of antenna diversity, frequency hopping, and speech post-detection enhancement.

An important aspect of the radio interface is the multiple-access method. Well known approaches are frequency-division multiple access, time-division multiple access, and code-division multiple access. Their principles are shown in Figure 6. All the second-generation systems employ time- or frequency-division multiple access or a combination of both. Thus the technology is

Figure 6
Some possible multiple-access schemes for cellular mobile radios



(*a*) Frequency-division multiple access

(*b*) Time-division multiple access

(*c*) Code-division multiple access

mature and well understood. However, the success of packet switched data networks over the years has also promoted the interest in packet radio-based multiple-access schemes such as the packet-reservation multiple access[22]. Their performance is dependent on the cell size and the carrier bit rate. Nevertheless, as noted before, packet radio-based multiple access would require a stable frequency reuse pattern for its operation, especially for services which would not tolerate re-transmission. As a result, packet radio multiple access may potentially be limited to data transmissions unless some form of longer-term dynamic channel-allocation scheme is proved to be able to enhance its performance. Nevertheless, in recent years, there is a keen interest in North America to introduce code-division multiple-access (spread spectrum) schemes into civilian mobile communications[27]. According to some predictions, the capacity gain of a spread-spectrum system could potentially be as high as 20 times that of an analogue system. However, spread-spectrum systems are known to be associated with technical challenges in the area of receiver complexity and precision power control. Its feasibility for use as a multiple-access scheme for the third-generation system has yet to be proven.

Still on the subject of the radio link, a further dimension which will affect the flexibility of the air-interface is the choice of the duplexing technique. Two types of duplexing techniques may be used. Time-division duplex is generally suitable for microcell and indoor environments where clusters of base stations could be synchronised in time. Transmit and receive cycles occur on the same carrier frequency but at alternate time-slots. The advantage is that there is no requirement for two sub-bands for the forward and reverse link. By contrast, the disadvantage is that a guard time is required between the transmit and receive cycles which is proportional to the cell size. Higher carrier bit rates could also lead to problems on delay spread and peak transmit power hazard in large-cell environments. On the other hand, frequency-division duplex (sometimes referred to as *dual-frequency time-division duplex*) is more suitable for large cell operations and the carrier bit rate is only half that of time-division duplex. This is because the system receives and transmits at alternate cycles at the mobile unit with timing advance allowed for at the reverse link. In addition, the forward and the reverse channels are assigned on two sub-bands with a guard band in between. Thus, an additional requirement is imposed on the spectrum allocation if frequency-division duplex is used. Nevertheless, the carrier bit rate is lower and thus the delay spread and peak transmit power problems are less severe.

This section has shown that the air interface may be influenced by many factors. Indeed its flexibility and efficiency are closely related to the design of the radio network. In the next section, some of the features by which the fixed network handles both mobility and the volume of signalling traffic in order to support the system will be outlined.

FIXED NETWORK

A third-generation system would not be complete without good fixed network support. For this reason, consideration has to be given to

(*a*) personal mobility,
(*b*) signalling,
(*c*) security,
(*d*) network architecture, and
(*e*) the integration/interworking with both existing and future networks.

Some of the key issues involved will be highlighted in the following.

With the rapid development of the universal personal telecommunications (UPT) concept within Europe, the third-generation system must be able to support UPT. UPT is a service which enables access to telecommunication services by allowing personal mobility. More specifically, it enables customers to make or receive calls, and obtain subscribed services, on any designated terminal in any supporting network and be charged, where applicable, personally. This service involves the network capability to locate the user on the basis of a unique personal (UPT) number for the purposes of addressing, routing, and charging. Thus, UPT will require the support of a network capable of handling a large demand for signalling interactions, routing identifications, and charging requirements. This can be provided only through an intelligent network with an associated database architecture[8]. The intelligent network concept generally enables the future proofing of the network by allowing the creation of services with flexibility and ease. The intelligent network is, therefore, independent of services and UPT requirements will only be yet another service entry within the network.

It is important to recognise that the amount of signalling traffic may increase significantly with the availability of personal mobility and new service offerings. The increase in signalling traffic will be due primarily to the need to transfer user information between service control points, and particularly to support handover, subscriber authentication, roaming, and location updating. Additional data required for call set-up could also be significant. The ability of the signalling to service the demand will depend on the dimensioning of the signalling capacity. Estimates have shown that the number of signalling transactions to be handled per second in an exchange could amount to three times higher than that without any mobile applications. Lack of capacity can seriously affect the quality of the overall network such as introducing call set-up delays. To this end, public key security and more efficient location updating procedures have been proposed to reduce the amount

of signalling traffic across the network. Moreover, with public key security, digital signatures for each transaction could be obtained to enable incontestable charging internationally.

Following the intelligent network concept, it was proposed that the call control and the connection control for the third-generation system be separated. Specifically, the status of the called customer is determined by means of a signalling channel before the actual connection is established. The connection is then set-up from the called party to the calling party. An obvious advantage is that the physical location of the called party could be established prior to setting up a physical connection. For instance, if two customers attempt to call each other while both are in a foreign country, only a local connection would be established.

With the significant increase in the number of base stations, the interconnection topologies within the base station systems will be different from that for the first and the second-generation systems. In particular, for the microcell base stations, a proposal has been made that they should be interconnected by metropolitan area networks[14]. The IEEE 802.6 distributed-queue dual-bus-based metropolitan area network standard appears to be a strong candidate for the application. One of the reasons is that it can support transmission in asynchronous transfer mode. It is also expected to be compatible with future networks and will be able to interwork with other network topologies including the star networks commonly used in contemporary cellular mobile systems.

Since future fixed networks are planned to incorporate *mobility features*, integration of the third-generation mobile functionalities into the fixed network is a possibility. Thus the third-generation system may be operated as a stand-alone mobile system or as an integral part of future fixed networks. Integration may come in terms of the unification of the database functionalities and the signalling system to include mobile requirements. Integration of exchanges to perform both fixed and mobile service switching is yet another possibility. However, for existing networks which do not have sufficient signalling capabilities, there may be a limitation on the range of service offerings.

DISCUSSION

From the previous sections, each segment of the third-generation system appears to be an area of technology development in its own right. There appears to be no easy answer to a full system solution. Many optimisations and trade-offs would eventually be required to ensure that all the techniques could inter-work with each other. We have already seen that there are many complementary techniques yet there are an equally large amount of conflicting and competing techniques. For instance, the incompatibility of packet radio-based multiple access and short-term dynamic channel allocation is a typical example. Furthermore, issues such as the subjective perception of echoes and transmission delay in relationship to the amount of channel protection and spectral efficiency must also be addressed. From the system design point of view, there must be no compromise on quality with technology until the final optimising stage. Likewise, achievement of an optimal system solution must not be restrained by existing mobile radio and cordless telecommunication standards. More research and verification work is still required to demonstrate the feasibility of each technical solution individually and their compatibility with the system as a whole.

In Europe, research activities on the enabling technology for creating the third-generation mobile system technique is already in progress under the Research and Development on Advanced Communications in Europe (RACE) programme. In parallel, the European Telecommunication Standards Institute (ETSI), the International Consultative Committee for Radio (CCIR) and the International Consultative Committee on Telephony and Telegraphy (CCITT) have provided European and international fora for the exchange of technical ideas and the formulation of guidelines on issues such as service requirements and technologies for the third-generation system. Within the CCIR, the subject is currently being pursued by Task Group 8 under the banner of 'Future Public Land Mobile Telecommunication Systems'[28]. The intention is that the third-generation system standard(s) will conform to a mutually agreeable framework accepted throughout the world. In addition, subjects pertinent to the third-generation system are also being studied within CCITT. For instance, within Study Group II, the traffic aspects (CCITT Recommendation E.750 series[29]) as well as the network performance aspects of future mobile systems (CCITT Recommendation E.220[30]) are being progressed. As can be seen, standardisation activities within international standard bodies on the third-generation system are already well underway. In fact, the future of the third-generation system now hinges upon a new spectrum allocation being made in the 1992 World Administrative Radio Conference. Currently, the proposal is that a band of 230 MHz could be made available in the vicinity between 1·7 and 2·3 GHz by around the year 2000. Other standardisation activities such as the universal personal telecommunications (personal mobility) standardisation work within ETSI will also have major impact on the third-generation system.

CONCLUSIONS

In order to support the demand of mobility in the next century, the third-generation system must not be merely a convergence of the second-generation mobile and cordless systems. The air-interface must be revolutionary and flexible in order to cope with multi-environment, multi-service operations. Yet from the service provision and the

network interworking point of view, the system must be evolutionary and be able to provide backward compatibility. This article has presented an overview on some of the key techniques which are currently under investigation for the third-generation system. All these techniques are aimed at achieving a system with better voice quality, better radio coverage, and better reliability but at an affordable price to the mass public. If the goal is achieved, the growth of the mobile communication market would be enormous. Likewise, the opportunities for the mobile communication community will be equally enormous. With this vision, the mission is to create a standard so that the dream third-generation system could become a reality before the end of the century.

ACKNOWLEDGEMENT

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Biography

Stanley Chia joined BT Laboratories in 1988 and is currently with the Radio Communications Division. Since 1989, he has led the Cellular Coverage Core Area in the European RACE Mobile Project conducting studies for the third-generation mobile system. He holds a B.Sc. degree and a Ph.D. degree and is a Member of the Institution of Electrical Engineers.

Skyphone

A. STUART†

BT has always been at the forefront of mobile communications with terrestrial systems and, more recently, satellite-based systems for maritime use. In September 1990, a major telecommunications milestone was achieved by BT with the launch of Skyphone™ to provide satellite mobile communications for aircraft. Skyphone is a registered trade mark for a consortium of BT, Norwegian Telecom and Singapore Telecom to provide a global aeronautical satellite communication service using the INMARSAT aeronautical system. This article describes the introduction of satellite communications to aircraft.

INTRODUCTION

Mobile communication is now a way of life for land-based and maritime customers. Maritime services have developed extensively over the past decade and mobile communications via satellite are now well established as the means for providing high-quality reliable global coverage[1, 2]. Special satellites designed for mobile traffic are in geosynchronous orbit and serve the world in four regions: Atlantic West, Atlantic East, Pacific and Indian.

Commercial satellite communication to aircraft has been considered since the inception of satellites, but, until recently, the technology has not been sufficiently developed to make the concept a practical and economic one. The drive for satellite communication to aircraft stems from both commercial and safety considerations. Commercially, the aircraft has in the past been an area where the telephone has not readily penetrated. While people have grown to expect a telephone to be available whether on land or sea, the air has until recently been a communications 'black hole' for passengers on long-distance flights.

Satellite communication opens the way for passengers to have direct-dial access to any part of the world from the aircraft. Passengers can benefit by the forward booking of cars and hotels and by keeping friends updated on estimated arrival times and unexpected diversions.

For the business traveller, staying in touch can be of great commercial importance. Users of private jets benefit not only from continuously available ground-to-air and air-to-ground automatic dialling communication, but also from an added element of privacy when compared with high-frequency (HF) communication. This is due to the complexity of the receiving equipment required not only to receive the signals from the satellite but also to decode the sophisticated digital signals used.

In addition to public demand, the aviation community has looked for a long time to satellite communications as a way of improving efficiency and safety. Airline operators can benefit greatly by having continuously available good-quality communication links with their aircraft. The benefits include better fleet management; faster turn rounds by the anticipation of stores, fuel and technical requirements; and economies achieved by closer control over routings and technical performance.

For air traffic control (ATC), the primary advantage of aeronautical satellite communications is the ability to provide good communication links over large sea and land masses. Reliable communications provides the means for greater safety and flow efficiency. For example, Atlantic air traffic, despite the sophistication of the modern jet liner, is controlled by ATC controllers in Prestwick who have no voice or radar contact with the aircraft. The controller relays commands to a trained HF radio operator in Ireland who attempts to pass the message over HF radio to the pilot. The vagaries of HF communication plus the two-step link between the controller and the pilot, lead to a slow and error-prone method of communication. In the absence of accurate and reliable positional information, the controller has to enforce large procedural spacing between flights thereby restricting the cross-Atlantic flow. Satellite communications can provide good-quality voice links directly between the controllers and pilots, with the additional capability of error-corrected data messages to ensure the correct reception of vital information.

In addition, satellite communications provide the means for automatic dependent surveillance, where each aircraft can automatically report its position derived from navigational systems by a data link to the ATC centre. The controllers are therefore provided with a pseudo-radar plot of the aircraft dispositions. In addition to the inertial navigation systems now fitted to most aircraft, other navigational systems on board can include not only traditional systems such as LORAN and OMEGA, but also the satellite-based global positioning system. With increased confidence in the

† BT Worldwide Networks

location of flights, the spacings can be reduced and the flow of traffic increased.

DEVELOPMENT BACKGROUND

In the early-1980s, BT recognised the long-standing need for aeronautical satellite communications and, acknowledging advances in technology, set about devising a system. INMARSAT, an international body of which BT is a member, was originally set up to provide space segment for maritime satellite communications but has now expanded its remit to other mobile systems. This organisation provides the satellites, defines the operating characteristics of systems using its space segment and regulates operation. INMARSAT soon became aware of the BT initiative and decided to commit itself to the concept of aeronautical satellite communications, and began designing systems for worldwide recognition. BT joined with INMARSAT in this task and participated in many discussions formulating the system design.

In addition, BT began an extensive trials programme involving avionics suppliers and British Airways to prove the technical viability of aeronautical satellite communications and to gauge customer reaction. The trials demonstrated that, while aeronautical satellite communication was a most difficult technical challenge, it was feasible with modern technology. Furthermore, the customer reaction proved to be favourable and indicated a tangible market in terms of passenger communications.

BT then demonstrated its commitment to this new area of communications by placing a major contract with a supplier for ground control equipment to provide a full INMARSAT compatible system. This ground equipment forms the heart of the current aeronautical service and is referred to as the *access control and signalling equipment* (ACSE). In addition, the Skyphone consortium of BT, Norwegian Telecom and Singapore Telecom was formed to provide worldwide access to the aeronautical satellite communication system from three strategic locations.

During the development of the ACSE, INMARSAT issued many system changes to correct specification ambiguities and improve the system integrity; the management of these changes became a significant problem. To ease these problems and to ensure compatibility, BT suggested a change freeze and the production of defined implementation levels. International meetings involving the various avionics suppliers, PTTs and potential customers were held to resolve these issues. BT had been the first PTT to place a contract for the ground control equipment and soon became heavily involved with design and system problems.

Finally, in 1990 the equipment was ready for testing in the factory in Oslo, and BT personnel witnessed the first set of formal tests. To assist in the testing and eventual routining of the equipment, BT had requested that an aircraft terminal simulator was developed to permit full end-to-end testing. This simulator was used extensively during the tests in the factory where calls could be set up, although not over the satellite at that stage. The equipment was then shipped, installed and integrated into BT's Goonhilly satellite earth station in Cornwall.

Another round of testing then took place culminating in calls being made from the aircraft simulator over the satellite and back to the ACSE. At this stage, the avionics suppliers were still developing their equipment and no aircraft had yet been fitted. However, some of the suppliers had prototype equipment and all parties recognised the importance of early compatibility tests. Test programmes were devised with INMARSAT's involvement and two of the avionics manufactures prepared for the tests. One of them, based near London, set up its prototype unit in the laboratory with the necessary antenna on the roof. The other, based in the USA, decided to bring its equipment to Britain to ease the coordination problems.

The avionics equipment was set up within the grounds of the Goonhilly earth station although entirely separate from the main operational equipment. The tests then commenced with BT coordinating the test programme with two competing avionics suppliers. The organisation and management of the tests was complex requiring careful balancing of the testing and correction time of both the avionics suppliers and BT's ACSE contractor.

The testing revealed some system design, equipment and compatibility problems, and a coordinated reporting scheme was introduced to track each problem. Regular meetings were held with the suppliers and INMARSAT. The interworking tests proved to be invaluable, not only for ensuring that problems were discovered before commercial service, but also as an opportunity to gain experience with the operation of the ACSE and the aeronautical system as a whole. The staff at Goonhilly were magnificent in coping with what was a very busy and challenging period.

In September 1990, INMARSAT authorised the BT installation as an approved ground earth station. At this time, no aircraft installation had yet been authorised; BT was therefore truly ahead of the field. BT continued to provide support to the avionics community and in November 1990 the first approved installation was airborne and the service began.

SYSTEM DESCRIPTION

System Design

The basic principles of the INMARSAT aeronautical satellite communications system are shown in Figure 1. The three key elements in the system are a ground earth station (GES), the satellite, and the aircraft (called an aeronautical earth station (AES)). The mobiles receive from the satellite in the 1·5 GHz band and transmit to the satellite in

the 1·6 GHz band (L-band), while the fixed base stations (the GESs) transmit to the satellite in the 6 GHz band and receive in the 4 GHz band (C-band). The satellite transponders carry out the required frequency translation between the C- and L-bands. The three main radio-frequency (RF) channels in the aeronautical system are:

- the R-channel (request channel from the AES to the GES),
- the P-channel (continuously radiated signalling channel from the GES to all AESs), and
- the C-channel (demand assigned channel), that is used to carry the voice traffic.

The P- and R-channels currently run at a channel rate of 600 bits/s but future channels are planned at higher rates.

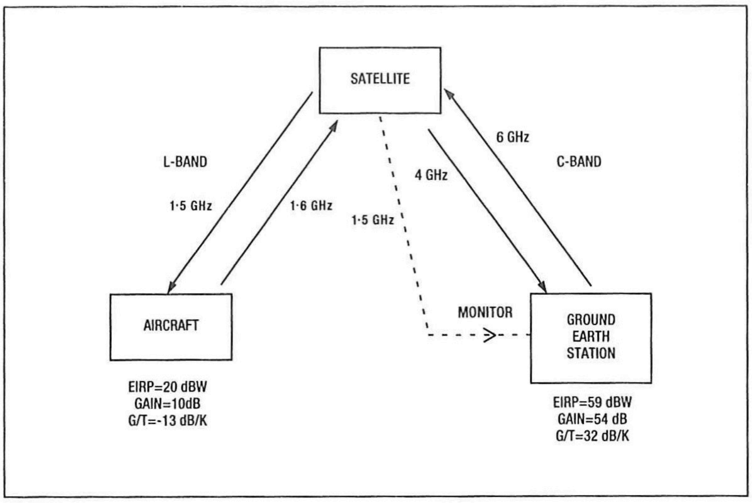
The basic method of operation of the system is by the allocation of single-channel-per-carrier circuits on a demand assigned basis originating from requests on the random-access request R-channel. A simple air-to-ground call set up is initiated by the AES sending a short request burst on the R-channel to the GES. The GES analyses the request and if valid sends back a message on the P-channel detailing which frequency to use for the voice-carrying C-channel. Both the GES and AES then begin transmitting on the assigned frequencies and pass test signals to ensure that the satellite link is good.

The terrestrial circuit to the international switching centre (ISC) in London is established and terrestrial signalling to the distant end is effected. On a successful answer, the GES records the time and the two parties converse. On call clear down, the GES records the time for billing purposes and releases the C-channel unit and frequency for subsequent use by another customer.

The GES has three constituent parts, the antenna, the RF equipment and the ACSE. The ACSE is the heart of the ground station system and includes the sophisticated coding and modulation equipment, a digital telephone exchange and computers with complex software to control the system. Calls made through the GES are controlled, routed and noted for billing purposes by the ACSE.

Coding and Modulation

The main advances in technology that have made aeronautical satellite communications viable are in digital signal processing, voice coding and phased array antennas. The practical problems of aeronautical satellite communications stem from mobile terminal weight and power limitations, antenna size and wind resistance, aircraft attitude excursions and an overriding concern for safety. These constraints on the avionics result in the installation providing only a relatively small signal towards the satellite 36 000 km away. Typically the aircraft will radiate an effective isotropic radiated power (EIRP) of 26 dBW at best and with an isotropic path loss to the satellite of around 189 dB, the signal received at the satellite is at a low level of -163 dBW ($0{\cdot}05 \times 10^{-15}$ W). For such a small signal to convey voice information using existing satellites and ground stations, the use of modern coding and modulation techniques became essential.



EIRP: Effective isotropic radiated power

Figure 1
Base station configuration

The first element of this is voice coding. Normal public switched telephone network (PSTN) speech entering the system at 64 kbit/s is passed to a special voice encoder developed by BT Laboratories and now established as the worldwide standard for aeronautical use. This voice encoder[3] codes the speech into a 9·6 kbit/s output thereby providing valuable information rate reduction.

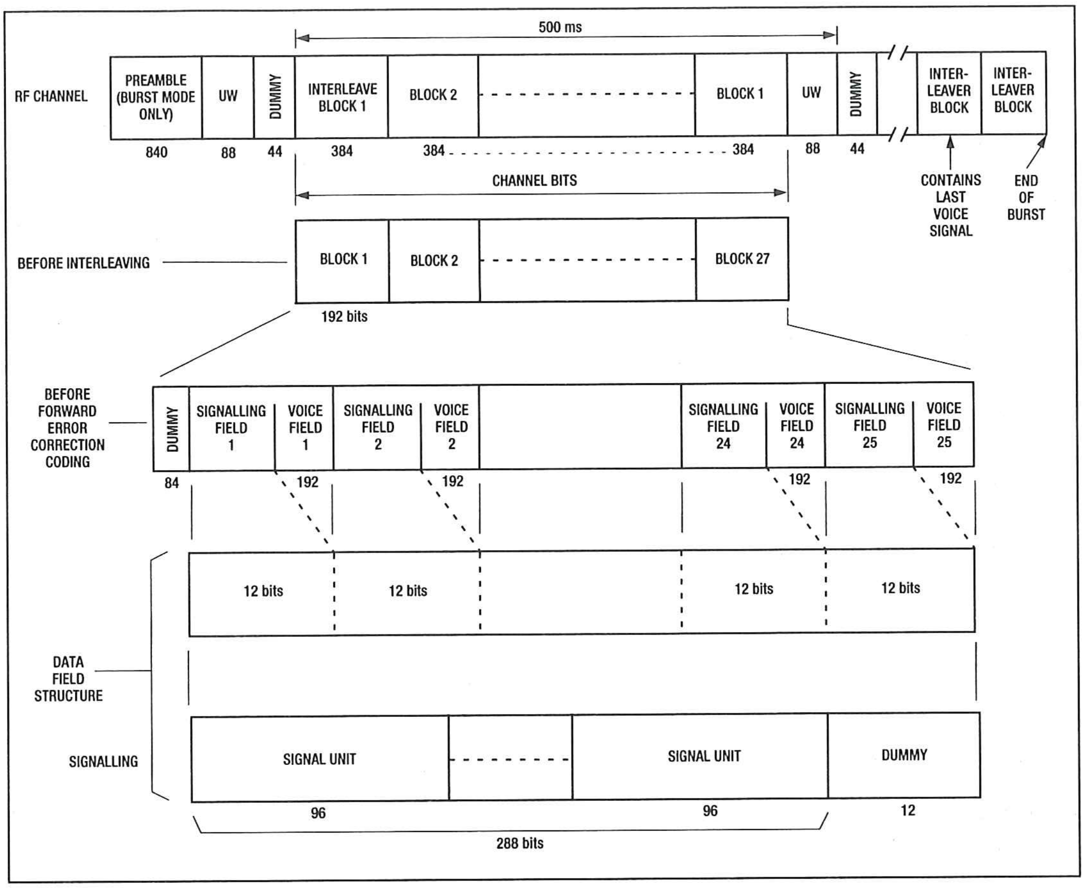
The second element is the process of additional coding and modulation. The 9·6 kbit/s speech is multiplexed with a signalling channel stream, and then the combined digital signal is scrambled with a pseudo-noise scrambler[4] to smooth out the spectrum. The output from the scrambler is then passed to a forward error correction coder, which, although doubling the effective data rate, provides for greater data recovery at the distant end. The output from the forward error correction coder is then split into blocks, which are interleaved to spread the information in the time domain. This is done to prevent sharp deep fades caused by multi-path reception that result from reflections of the incoming satellite signal from the earth and aircraft body and cause total loss of information.

Finally, the bit stream is framed and sent to an RF modulator with an effective channel rate of 21 kbit/s producing offset quaternary phased shift keying (QPSK). Figure 2 shows this channel format. The distant-end terminal performs all of these sequences in reverse to recover the 64 kbit/s speech.

System Control and Space Segment Utilisation

In common with most satellite communications systems, the link margin is low, in the order of

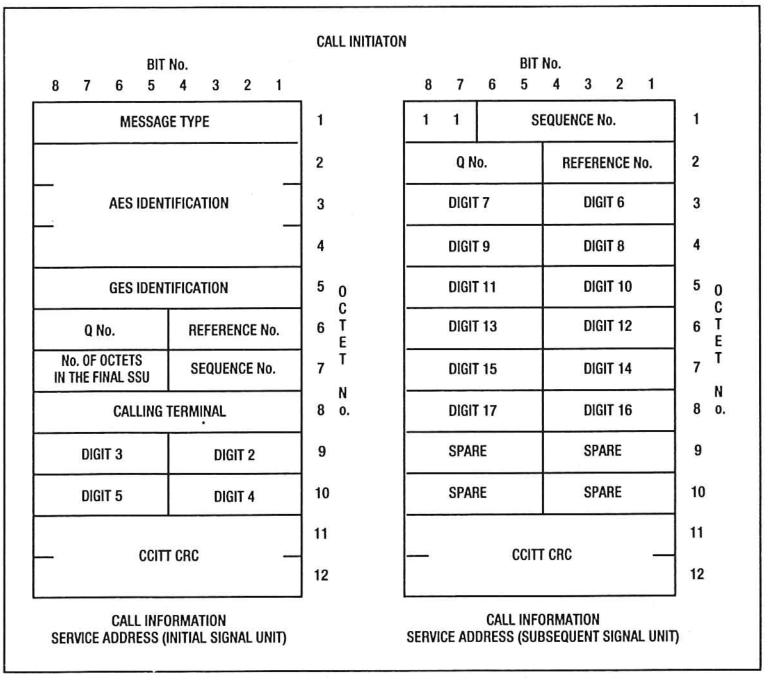
Figure 2
Voice C-channel format for 21 000 bit/s transmission rate, 9600 bit/s voice rate



UW: Unique word

Figure 3
Example signalling units

2 dB, as the costs associated with achieving higher link margins are not economic. The major variability in the link is the geographical location of the AES, and the orientation of the aircraft antenna with respect to the satellite. To assist with these variables, an interesting feature of the system is the closed-loop both-way EIRP control mechanism. As the aircraft changes attitude and location, the signal it sends and receives from the satellite varies. As the link margin is so small, the forward and return signal levels need to be adjusted in real time to compensate for these variations. This is achieved by the AES monitoring the received bit error rate and reporting this over the signalling sub-band to the GES. The GES then analyses the report and automatically adjusts its radiated power on that circuit accordingly to try and attain the required bit error rate at the AES. Similarly, the GES monitors the received bit error rate from the AES and, after analysis, commands the AES to raise or lower its power. Should the AES travel to the edge of the coverage of a particular satellite region, the avionics will sense the degradation of the signal received from the satellite and transfer the service to the next adjacent satellite region.



Q No: Priority code CRC: Cyclic redundancy check

Signalling and data transfer is accomplished by the use of signal units. These are blocks of information usually 8 by 12 bits long and are formatted in a predefined manner. Each signal unit has a header defining its type and thereby the way to interpret the following fields, followed by specific fields of data, with the last 3 octets of the signal unit containing a cyclic redundancy check sum. This method of packetising the signalling provides for clear computer processing and integrity of the information. Examples of signal units are shown in Figure 3.

Table 1 compares key system parameters of the aeronautical system and maritime INMARSAT A system. The key differences are the use of voice coding and digital modulation and the lower mobile power required for the aeronautical system. Another advantage of this, from a space segment viewpoint, is the lower spacecraft power required for the aeronautical system. To reduce the burden on the satellite even further, voice activation is applied to the forward (GES–AES) carrier. Over a large number of carriers this can provide significant savings on spacecraft power.

TABLE 1
Comparison of the INMARSAT A Maritime Satellite System and the Aeronautical Satellite System

	Maritime A	Aeronautical
Mobile antenna	1 m steerable	Slim phased arrray
Mobile G/T	–4 dB/K	–13 dB/K
Mobile radiated power	36 dBW	20 dBW
Channel spacing	50 kHz	17·5 kHz
Modulation	Analogue FM	Digital QPSK

Customer Interface

From a passenger's perspective, the service is very easy to use. Although installations on aircraft will differ, the principles remain that the customer has access to a cordless telephone and credit card reader. The customer swipes a credit card through the reader and dials the number required followed by a GO command. For a normal PSTN call, the digits dialled are 00 followed by the international country code and then the rest of the number. For special services, the customer can dial a range of 2-digit codes other than 00. The call is then set up automatically and proceeds in the same way as any other call as perceived by the customer. At the end of the call, the customer clears the call and replaces the cordless telephone. In due course, the charge for the call appears on the customer's credit card bill. Users such as corporate jets and airline operations can have account charging.

Both ground-to-air and air-to-ground calls are provided easily with satellite communications, but there are addressing problems associated with ground-to-air calls to passengers on commercial flights. The first problem is to define how a ground customer could indicate the aircraft and person required by using dialled or dual-tone multi-frequency digits over the PSTN. The second problem relates to ensuring that the incoming call to the aircraft is made known to the called party with the minimum of disruption to cabin staff and adjacent passengers. However, for corporate jets this is not a problem and PSTN ground-to-air calling is possible by dialling the British international access code followed by the satellite ocean region the aircraft is believed to be in, followed by the aircraft's unique 8-digit number, (for example, 0108751xxxxxxxx). Currently, over 30 corporate aircraft use this facility.

Data Transmission

In the future, data message transfer will occur by the use of the P-channel in the forward direction and by a new T-channel from the aircraft to the ground. This T-channel will be a time-division multiple-access (TDMA) channel with time-slot allocations demand-assigned by the GES. Data originating in X.25-type packets will be reformatted into satellite data packets which are then transmitted over the aeronautical satellite communications system by using the signal unit convention mentioned previously. At this link layer, the GES and AES check for correct receipt of each signal unit and a re-transmission protocol operates to ensure the correct flow of information.

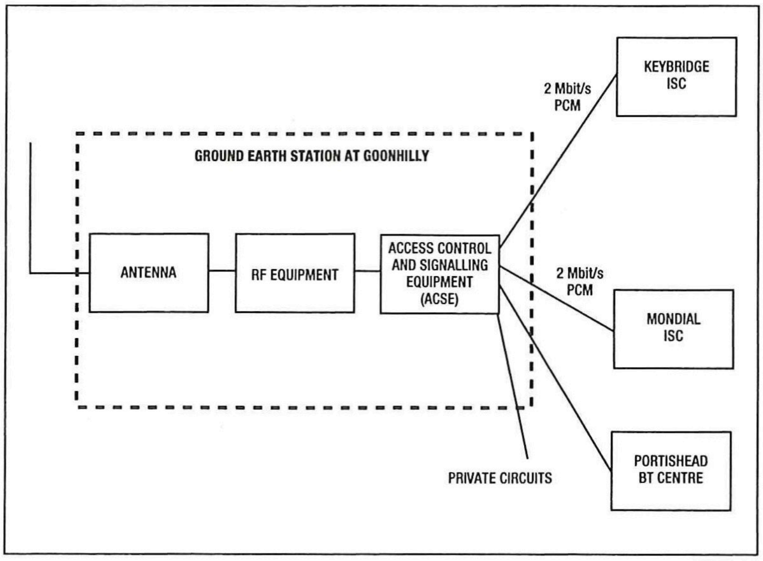
In addition to performing the link service, the ACSE also has to be involved at the network layer and determines routing and associated network parameters. This involves the addition to the ACSE of new software and a data packet switch that will interface with private X.25 lines, as well as the public packet switched network.

IMPLEMENTATION

The Skyphone service is provided by BT's Goonhilly earth station. The basic configuration is shown in Figure 4. Coverage of the East Atlantic region is currently provided by Antenna 7 in conjunction with Antenna 12. Antenna 7 provides the C-band links to the satellite while Antenna 12 provides L-band communication for monitoring and for use by the Goonhilly AES simulator. Expansion of the service in the West Atlantic area is planned with the ACSE then additionally feeding Antenna 5. This antenna is capable of both C- and L-band communication.

The ACSE is housed in a special wing at Goonhilly dedicated to satellite mobile products. The ACSE is designed on a distributed sub-system basis with a common Ethernet as shown in Figure 5. This

Figure 4
Ground segment configuration



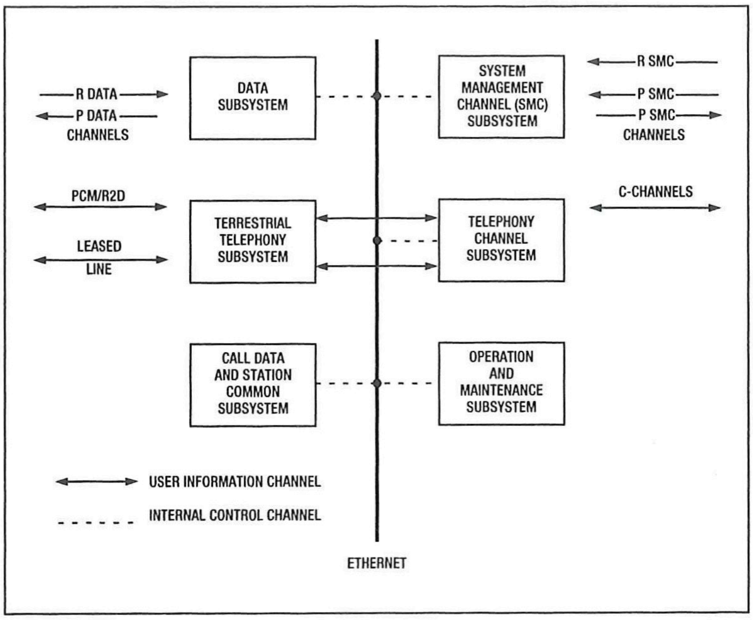


Figure 5
ACSE block diagram

functional distribution avoids hubs of complexity, aids fault location and increases service reliability. The processing power in most of the subsystems is provided by discrete purpose-built 186 and 286 microprocessor computers.

The call data and station common (CDC) subsystem manages the resources of the system and controls the call from a high logical level. Information relating to a call is also sent to the CDC subsystem from other subsystems for collation and saving onto hard discs within the CDC subsystem. The terrestrial telephony subsystem is a complete digital voice switch connecting the channel unit modems to the terrestrial lines. The switch supports full international R2 signalling on 30-channel 2 Mbit/s connections and earth-and-mark signalling for private circuits. The system management channel (SMC) subsystem controls the primary P and R satellite signalling channels while the telephony channel subsystem controls the voice communication C-channels. The CDC and SMC subsystems are both configured in a one-for-one redundancy arrangement with automatic changeover while the traffic-bearing channel units and voice switch have soft fail capabilities providing reduced capacity under fault conditions. The operation-and-maintenance subsystem differs from the other subsystems in that it is based around commercial DEC computers and thereby makes full use of available database software.

The operational ACSE is contained in two 5 m length suites, one with the controlling computers and voice switch and the other with the RF channel units. Equipment practice is common for the two suites and the normal operating condition is with the cabinet doors closed, thereby presenting a clean uncluttered appearance with no external lights or controls. Operator interaction with the ACSE is via computer terminals and is minimal during normal operation.

At predefined intervals, billing information is dumped from the ACSEs hard discs to magnetic tape for transfer to the BT computing centre at the Barbican where bills, accounts and reports are generated. The ACSE contains an intelligent fault-reporting system where hardware and software alarms are processed by a computer, which produces an output indicating where the fault is most likely located and lists possible actions that should be taken to remedy or further investigate the problem.

In attempting to define unambiguously the logic of operation of the system, INMARSAT decided to adopt the use of the Specification Description Language (SDL)[5]. To provide clear traceability from the INMARSAT system design to the implementation in the ACSE, BT and the ACSE supplier agreed that SDL would be used in the detailed ACSE design. This decision proved to be very worthwhile in the testing and fault-location phase. The application code was written in Intel PLM-80 language and structured to reflect the nature of the SDL design in terms of states, events and signals. Furthermore, the ACSE contains a powerful built-in diagnostic tool called *TRACE*. This tool can be set to show exactly what has happened, in terms of the software code, for a specific event. It reports which branch of code was executed, the input and output signals and the next state accessed.

This report can be aligned with the SDL documentation from which the code was originally generated, and a quick and effective analysis of the ACSE operation can be performed. This deep insight into the computer operations of the unit is invaluable for diagnostic work.

In addition to the main ACSE, there is a maintenance unit where off-line testing can be performed, and an AES simulator. The AES simulator at Goonhilly is an independent unit which can be used to generate an AES call over the satellite. This facility is useful for testing and routining to ensure the correct operation of the GES equipment.

The current initial configuration of the BT GES at Goonhilly allows for up to 16 simultaneous calls. The ACSE has two 2 Mbit/s 30-channel pulse-code modulation connections, one to Keybridge ISC and one to Mondial ISC using R2 digital signalling. In addition, various private wires are connected to the ACSE for commercial and operational use. Automatic ground-to-air calls can be made from most parts of the UK. The ACSE supports short-code facilities whereby the airborne customer can dial a 2-digit code to access specialised services such as operator assistance and a connection to BT's Portishead communication centre, which is at present the hub of BT's long-range maritime and aeronautical HF communications.

BT is currently serving more than 30 aircraft, with major airlines now fitting out their long-haul fleets. Singapore Airlines is now flying with the first Boeing 747-400 fitted with aeronautical

satellite communications equipment. Figure 6 shows the 747 and the small satellite communications antenna can just be seen at the top of the fuselage midway along its length.

FUTURE

The aeronautical voice service is now firmly established with 11 ground earth stations, some in competition with Skyphone. In addition to corporate jets, the major airlines are now introducing the facility. While the initial voice service grows, there is an ongoing programme to enhance aeronautical satellite communications services. Developments underway include the provision of data and facsimile services. The data service is of prime importance to the airline operators and ATC agencies. In addition to enabling regular navigational and status reports from the aircraft, the data systems, which will be X.25 based, will allow for connection to many networks, both private and public, worldwide. For the passenger and private user, developments being considered include facsimile and data transmission, and secure speech systems.

CONCLUSION

The opening up of the last frontier of satellite communication has not been an easy task, but with drive and commitment BT has played a significant role in establishing aeronautical satellite communications. The benefits for many users will become apparent as the system expands and the opportunities for additional services are many. It will not be long before telephones on long-distance aircraft are viewed as the norm.

Figure 6
First Boeing 747 to be fitted with aeronautical satellite communications equipment

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5 Functional Specification and Description Language (SDL), CCITT Recommendations Z.100-104.

Glossary of Terms

ACSE	Access control and signalling equipment
AES	Aeronautical earth station
ATC	Air traffic control
CDC	Call data and station common (subsystem)
EIRP	Effective isotropic radiated power
GES	Ground earth station
ISC	International switching centre
PSTN	Public switched telephone network
QPSK	Quarternary phased shift keying
SDL	Specification Description Language
SMC	System management channel
TDMA	Time-division multiple-access

Biography

Alan Stuart is Manager of Aeronautical Projects in Worldwide Networks. He joined BT as a sponsored student in 1971 and after graduating in Physics at Surrey University became responsible for the procurement of general-purpose test equipment throughout the business. In 1982, he transferred to satellite communications work and was involved with the provision of the first two 11/14 GHz terminals installed at Madley earth station. Since 1985 he has been involved with satellite mobile communications with particular emphasis on the definition and procurement of ground control equipment.

Adaptive Quality Management Systems

A. PENGELLY, R. HIGHAM, M. NORRIS †

The use of quality management systems (QMS) and associated BSI and ISO‡ registration are increasingly seen as the first step in introducing control into processes. However, to address the evolutionary quality philosophy of total quality management (TQM) and increasing customer demands, the QMS must possess the means to adapt to changing needs. This article discusses how process modelling and measurement can aid the introduction of control mechanisms, thereby endowing the QMS with the mechanism from which change can be objectively undertaken.*

INTRODUCTION

There is a growing number of companies possessing BS 5750 or ISO 9001 registration in the UK. BSI or ISO registration imparts a status onto an organisation which reflects the company's quality awareness. Typically, this has involved the installation of a quality management system (QMS) which imparts a degree of control on the support structure within the organisation. Hence product reviews are formally documented, as are project plans etc. Although initially designed for manufacturing processes, BS 5750 does translate quite well to non-manufacturing processes. However, ISO 9001 does not necessarily guarantee quality products. So, for many companies, a QMS is closely related with more general quality drivers, such as total quality managment (TQM).

Whereas the whole philosophy of TQM is one of evolutionary and continued improvement, the QMS and associated registration tend to be 'snapshots'. There is usually considerable reluctance to change the QMS once it is in place, even though the TQM process may have taken the company further down the quality path. As a result, the QMS can become rather bureaucratic, inflexible and outdated. Indeed, it can hold back the pace of quality improvement. This phenomena of degradation is generally referred to as *process entropy*. In order to address not only the evolutionary quality of TQM, but also the increasing demands for higher quality products from customers, a degree of 'liveness' needs to be incorporated into the QMS which enables it to adapt to these changing needs.

The inclusion of a measurement capability is a necessary first step. Measurement can be used to address the notion of an 'improvement-oriented' process[1, 2]. However, the basic prerequisites for adaption, using terminology from control theory, are feedback control mechanisms with appropriate update algorithms. This requires two pieces of information. The first is estimating what the next state ought to be; the second is assessing the actual state and deriving the difference, whereby the update algorithm makes appropriate changes. Ignoring the technicalities, the corresponding need in product development is estimating and assessing product and process attributes. This procedure is often termed *closing the loop*. In terms of modifying the process as a result of differences, it is, like the adaptive algorithms of control theory, a question of learning from mistakes.

The discussion in this article extends the concepts devised by Stockman[3] with regard to developing a formal and constructive approach to quality in the software industry. In particular, Stockman's underlying mathematical model forms the basis for much of the ideas discussed here.

The article begins with an overview of current best practice regarding process measurement. This is followed by the development of a *formal framework*, which amounts to a process model with a description of the embedded control mechanism. An example of applying the ideas to a QMS is then discussed in a software development context, though the general principle will be the same for any process. The article closes with a conclusion and a discussion of future work.

QUALITY

Quality Management Systems

The aim of constructing a QMS is to make the process repeatable. The cornerstone of the QMS is quality planning. Plans embody the process, and are designed to be capable of delivering the required quality at minimum cost. It should also encapsulate a process designed to remove errors (deviations from specification) as early as possible. Such plans have a tendency to be cast in stone; improvement in planning occurs only as a result of product failure in the implementation phase. Owing to the length of life cycle updates, improvements, if attempted at all, are slow, and can only impact on future products. Changes made to future processes may actually be inappropriate. It there-

† BT Development and Procurement
* BSI—British Standards Institution
‡ OSI—International Organisation for Standardisation

fore becomes important to make quality planning 'real-time' as in process industries. That is, the process should be adapted in the light of continuous feedback from as early in the life cycle as is possible. Only in this way can it be assured that the end product is fit for purpose. It may be that in the future the rate of adaption will be slowed as the relationship between the process and quality states is fully understood.

Total Quality Management

In practical terms, TQM is about achieving a level of process sophistication which amounts to a managed and optimised system. The application of TQM is best demonstrated by the Japanese car industry. Cars have been manufactured in Japan since the 1920s. But exports only took off in the 1960s. The methods used to gain a lead in car production is the same one applied to the motorcycle industry, TV, radio, ship building etc. First find or invent (in the case of the Walkman) a market niche. Supply your product at the same price but to a better specification than your competition. In the case of the car industry, supply a heater and radio as standard when your competitors supply items as optional extras. This is line A in Figure 1. You then improve the quality of your product but keep the price constant by using the quality control approach to production. Your competition cannot compete on quality and hence must reduce profit margins to compete.

To meet the practical demands of TQM, the QMS needs to be continuously extended. This is done by first defining a formal model of the process[4]. Hence, the model provides the link with the QMS and process evolution. Secondly, a measurement programme is established, based firmly on the derived model. A feedback cycle is then established to enable the process to be both managed and optimised (adapted), see Figure 2. The key message is *model, analyse and execute.*

A Model for Quality Improvement

Central to Stockman's model is the notion of a *quality vector*. The vector describes the state of a product at some particular stage of the process. The components of the vector are metrics which measure attributes of the product. Clearly, the larger the number of metrics, the finer the resolution in terms of characterising the product. As the product evolves, the quality changes; in this way, the process can be viewed as a series of transformations that operate on the vector.

MODEL, ANALYSE AND EXECUTE

A Formal Model

A theoretical framework can be established in which the derived measures reside. This formal framework is basically a high-level description of how the modelling and measurement disciplines are combined. In fact, *process modelling* (also referred to as *business modelling*[6]) is not only an active area of research, it is also being applied by several major companies, including BT. The model reflects the organisations' understanding of how it carries out its business. Clearly, such an understanding is crucial before any objective process improvement can be undertaken. In particular, the model provides the basis for the measures, which are derived in accordance with the quality goals. A good overview of process modelling can be found in References 4, 5 and 6. As already stated, the primary concerns are products of known quality and control. There are four basic prerequisites[7]:

- there must be a well defined goal,
- there must be possibilities for ascertaining the state of the system,
- there must be a model of the process, and
- there must be possibilities for affecting the process.

These concepts need to reside within a meaningful structure, which reflects the way in which the process is managed in a quality-conscious organisation. The aim is to evolve the process via quantitative information generated by the measures. Hence a feedback mechanism needs to be established whereby differences between expected and actual 'quality' can be addressed, by adapting the

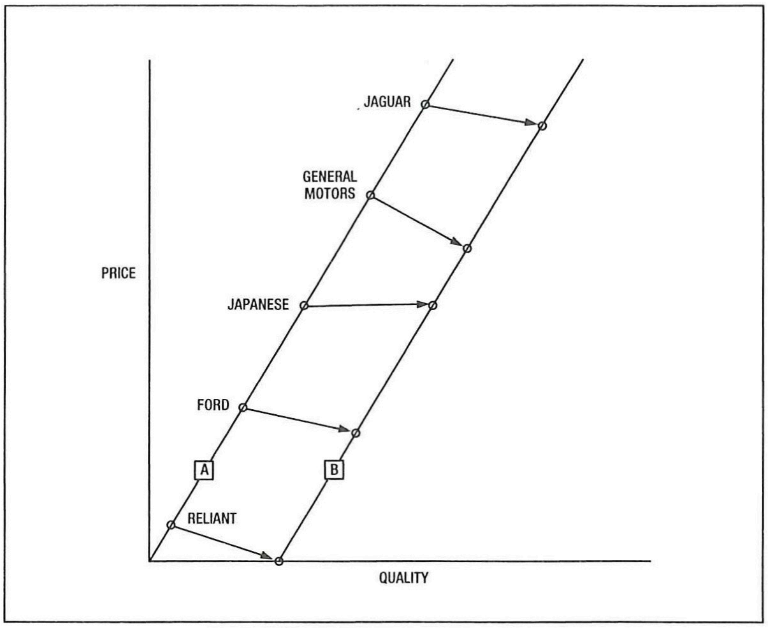

Figure 1
TQM in action: Japanese car industry

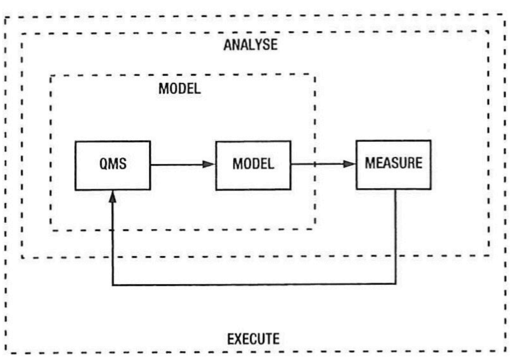

Figure 2—Model, analyse and execute

process in a way which redresses the shortfall in quality. This amounts to adopting standard techniques from control theory[8].

By using standard techniques from control theory, one can establish a notion of a *state space*, and, by using this as a basis, derive a *product quality space Q* where the coordinates are the relevant product attributes. These attributes describe the key characteristics of the entity under observation, in terms of predefined quality targets. Hence a product, at any point of its evolution, can be represented by a vector **q** in Q. As such the development of the product can be visualised as a series of transformations on Q throughout the process[3]. The important point here is that it is the action of the *process* that transforms the product from one state to another, in order to get to the system required by the customer. The process is described via process metrics which provide the coordinates of the *process quality space P*. The 'state' of a process is represented by a vector **p** in P. These metrics would be derived from a process model[9]. Hence the appropriateness of the process to the production of quality products can be assessed, and, if need be, modified on the basis of the information being supplied from the measurement of those products. Such enhancements to the process are a result of output from the feedback mechanism which uses data from Q. The procedure can be summarised as follows:

1. Construct the process model.
2. Develop appropriate product measures, defining Q.
3. Develop appropriate process measures, defining P.
4. Define product quality targets (estimates).
5. Compare 4 with actual quality.
6. Modify process model on the basis of the difference between 4 and 5, and simulate on a computer if possible.
7. Modify the real process.
8. Develop new product and process metrics if appropriate.
9. Repeat steps 4 to 9.

This can be represented pictorially as shown in Figure 3.

This procedure links the measurement and modelling disciplines into an integrated whole. It should be pointed out that, when dealing with processes dominated by people (for example, non-automated production processes), there is a large element of uncertainty which results in data which is essentially statistical or stochastic. Indeed this is true, though to a lesser extent in general, even with automated processes. The stochastic nature of the above procedure is a result of the non-determinism in the process, since people behave in essentially different ways within the confines of the system or process[10]. What can be done is to define a notion of expected behaviour. This non-determinism manifests itself in a *noise* component, which distorts the data somewhat.

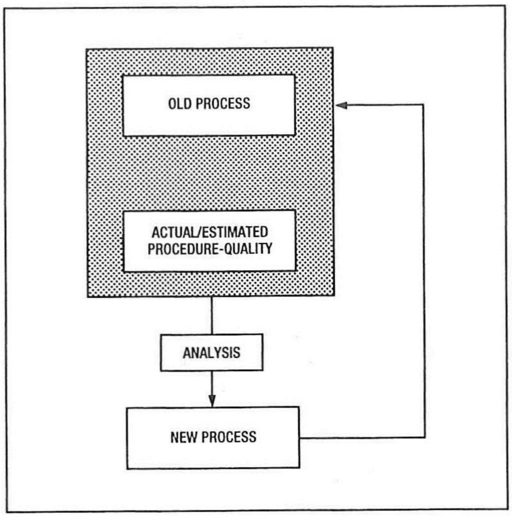

Figure 3—Graphical representation of the adaption procedure

Clearly these rather simple statements belie the true complexity of actually being able to perform such a task. The basic causal relationships between the process and the product need to be understood, since the above procedure has to quantify these relationships in order to operate effectively.

This is quite similar to the approach adopted by Box[11]. What Box proposed in his paper amounted to randomised changes to the process; that is, the process was altered without any reference to causal relationships between product and process, although they were assumed to exist. As with the process of natural selection, changes that benefitted the product quality were kept while those that did not were discarded. However, such an approach would seem to require an inordinate degree of patience, which is probably not appropriate in today's economic climate.

If all of this seems rather elaborate, the authors would point to similar work being undertaken by a Japanese company where process 'learning' is simulated via a metrics-based model implemented using neural nets†. In addition, the University of Dortmund has also been carrying out some interesting work regarding process simulation[12, 13].

Clearly, if one is to develop an integrated measurement programme, some means of predicting or estimating the product characteristics needs to be found. In turn, this requires an early measurement capability at an early stage of the process or each sub-process. Early adoption of the process as defined by the QMS or quality plan will increase the likelihood of delivering the appropriate product qualities required.

Analysis—An Example

By quantifying key attributes of the QMS (the process) and the products produced, and by

† The authors understand that this work is soon to be published

developing a predictive capability, the ideas behind the formal framework can be applied. The QMS will be modelled by P and the product by Q. The feedback mechanism, via the procedure described in the previous section, can be realised in a number of ways, depending on the maturity of the adaptive process. In the absence of clear relationships between product and process, formal reviews or 'brainstorming sessions' could be used. At the other end of the spectrum, the procedure could be applied automatically, though this is clearly dependent on a number of advanced, though not unattainable, developments in process engineering. As stated earlier, the Japanese are already moving towards this.

If the assumption is made that the starting point is a typical QMS with a 'current-best-practice' measurement facility, what are likely to be the first steps undertaken to develop the adaptive capability?

Consider the following hypothetical scenario from a software development process:

During the coding phase, it is found that the specification of several functions appears to be incomplete or anomalous. Two possible causes are identified. The first is that the requirements capture process was not carried out effectively. The second is that the review of the formal specification did not reveal the key problems for some reason. The relevant measures are collected to investigate the issue.

The complexity measures of the system reveal, via outlier analysis, that the problematic functions are complex, more so than usual. Metrics from the requirements capture process indicate that although the process was difficult, these functions did receive the most attention. Attention is then turned to the specification itself and the review mechanism.

Analysis of the review data reveals the problem. Reviewers were asked to review the whole specification, which is both technical and long. The review itself lasted 4 hours. There was no priority rating given to the complex functions, and they were scattered throughout the specification. When the review started, a relatively large number of errors were found; the error-rate (say errors per 15 minutes) gradually dropped off as the review proceeded. This manifests itself in the normalised error-density (say errors per function per complexity or size unit) likewise dropping-off as a function of time. In addition, the review productivity rating (say pages per hour) increases as the review progresses. During the last 15 minutes, virtually no errors were found, even though a particularly complex function was examined. The conclusion could be that the reviewers lost concentration and became ineffective.

In this case, the product (the specification) has suffered as a result of the review mechanism. On the basis of the measurement data available, the review mechanism is changed with the following list of actions identified:

- The specification should be written with the most complex functions at the beginning where possible.
- Key aspects/words in the specification should be highlighted to ensure shared understanding.
- Each function has its complexity value clearly indicated on the specification. Possibly a function complexity/size scatter plot is included.
- Each reviewer is assigned a subset of functions to review. The most complex are assigned to the most experienced.
- The review chairperson should monitor the error rate as the review proceeds. If a drop-off is detected, the review is to be brought to a close, to be resumed after a suitable pause.

Execute

Notice that even in this rather simple example several relatively advanced practices are required. These include the use of formal specification languages and the ability to measure them, a clearly defined requirements capture process with associated measurement, and the collection of 'real-time' review data. Regarding the formal framework, the product space Q is spanned by the attributes of complexity, size and error density. The review process space P is spanned by duration, error-rate and productivity. The objectives, as far as process adaption (improvement) is concerned, are to stabilise productivity and error-rate and reduce duration. The increased level of understanding regarding the review process leads to new measures being defined. In this case, these could be the mean and variance of the productivity and error-rate data.

From the product point of view, there seems to be an issue regarding usability of the specification, hence a syntactic measure of the product could be collected (for example, Fog Index). Also the ordering of functions in terms of complexity needs to be addressed. A particularly simple measure of this would be to multiply the function complexity by its numerical position in the specification. In this case, a minimum value is reached when the most complex functions are at the beginning while the simplest are at the end. The improvements would be validated by observing the effect on the product. It might be expected that the resulting product data will exhibit a strong correlation between complexity and denormalised error-density.

So what improvement could be made? In this hypothetical example†, there are two problems. The first is the nature of the review itself, how it is constructed and implemented. The second is with the product and its seemingly inappropriate structure.

The above example represents a feedback loop between design and implementation. Similar feedback mechanisms would need to be placed

† Though the problem alluded to is a common one among review techniques

across the development process. What will be apparent from the above is that the evolution of the QMS will need to be effectively managed.

Measurement is clearly an absolute prerequisite: without it very little can be achieved. In terms of quality by inspection, control, improvement and design, most organisations using a QMS in conjunction with metrics are at best at the *control* phase[9]. The adoption of the above most certainly moves an organisation into the *quality-by-improvement* phase. Developing an integrated measurement capability is the only way an organisation can progress to the desired *quality by design*.

PRACTICAL IMPLEMENTATION

Implementation of such an approach requires that process engineering and management improves its ability to:

- design and define the processes that it uses at all levels not just at the level of project and product life cycles;
- put in place effective mechanisms for updating and disseminating changes made to processes as a result of feedback taking place; and
- ensure that, as a result of identifying improvements, behaviours change and not simply the documented process[15].

As a discipline, measurement is difficult to implement, at least in part, because of a lack of understanding of the processes. In quality terms, failures occur in effectively designing and implementing the processes to be used to ensure product quality, yet this is the essence of quality planning[14]. Only then can effective measurement be achieved.

Once the measurement and control loop is in place, and assuming we have a rapidly changing environment, how can the documented system keep pace with the constant change; that is, how can the improvements be locked in? The impact of the type of approach suggested in this article on the 'documented system' is likely to be significant. Many quality systems rely too much on paper and words to document processes. New approaches, in particular the use of 'on line' and 'graphical' techniques will need to be introduced. 'Process ownership' may need to move from centralised systems to locally owned descriptions, with only common aspects documented at a high level.

An environment which is designed to constantly change will also have a major impact on the people involved. It is not sufficient to update the documented process and hope that behaviours will change as a result. It will be essential to create an environment that supports a culture of change and rewards those who are prepared to experiment with the processes being used. Without such a culture, experience suggests that improvement will be at best slow and at worst stagnant.

Having identified these issues, and doubtless many others exist, it is important that the first steps be taken quickly. As the preceding example shows, this approach can provide significant gains in process improvement. Providing one accepts the limitations of current best practice and is prepared to make some assumptions, much can be done now; for example, in the example, subjective assessment of the complexity of specifications could be used in place of formal measurement. If quality improvement is to proceed within process engineering, it is essential to recognise that formal engineering practices, and in particular formal measurement, are not prerequisites. Indeed, some may argue that to reach the status of an engineering discipline, we will need to fully exploit the 'craft' side of our work.

CONCLUSION AND FUTURE TRENDS

> 'We only find out what we'll do, by finding out what we'll not do.' *Samuel Smiles, 1901*

Quality improvement is a continuous process which necessitates change from an organisation in order for it to remain competitive. To remain static is to be falling behind. A process (QMS) will not change of its own accord. Likewise, change for its own sake could prove just as damaging. However, directed change, using measurement and control principles, provides the focus by which a company can address the central issue–the development of quality processes and products.

The ability to measure and predict, coupled with the formal framework, are the necessary tools required to establish feedback mechanisms across the process, and hence provide the capability for controlled evolution of a QMS or any other process. Such evolution is dependent on establishing pertinent relationships between the product and the process. This is unlikely to be a trivial task, and will require a commitment of time and resources.

While this article has concentrated to some extent on the software development process, the approach adopted is applicable to any process.

In the meantime, the only thing that is clear is that, in an environment of continually changing demands, the QMS must change at an equivalent pace.

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Biographies

Alan Pengelly joined BT in 1987 from Ferranti Computer Systems, working initially on the signal processing for the ISDN local loop transceiver, automatic service recognition and transmission in the local loop. In 1988, he moved to the Software Development Division, BT Development and Procurement, where he currently leads a team responsible for developing and downstreaming measurement and specification techniques aimed at improving quality and performance for both products and processes. He is an Associate Fellow of the Institute of Mathematics and its Applications and has an honours degree in Applied Mathematics.

Bob Higham is Divisional Quality Manager for the Software Technology Division in BT Development and Procurement. He joined the then British Post Office in 1970 as a Trainee Technician Apprentice in London South Centre Area. He has worked in local and trunk exchange maintenance in both London and Cardiff. He spent five years as a Technical Officer working in the Cardiff measurement and analysis centre, before gaining promotion to Assistant Executive Engineer and moving to Research and Technology in 1982. He spent six years working in his division's software maintenance team, much of that time maintaining the UXD5 exchange software. During this period, he gained promotion to Executive Engineer. He moved on to the Software Metrics group in 1988 and was promoted to his current position in 1990. He has a postgraduate diploma in management studies and is a member of the BCS.

Mark Norris received his B.Sc. and Ph.D. degrees from the university of Glasgow in 1976 and 1979, respectively, before joining BT Research Laboratories in 1980 to work on local network signalling systems and interfaces. His work since has encompassed implementation of the ISDN, high-speed local area networks interface test euipment and software maintenance. He currently heads the Systems Design Metrication and Testing section. He is also responsible for divisional training and coordination of publications. He is a member of the IEE and a Chartered Engineer.

BT News

Dixons Improves Customer Service and Enhances Store Management Through BT's Global Network Services

Dixons Stores Group (DSG), part of Dixons Group plc, the UK's leading specialist retailer of consumer electrical and electronic goods, has chosen BT to provide a customised managed data network service. The deal is worth £6·5M over five years.

By using a BT customised managed data network solution, Dixons will have the benefits of a private network, while avoiding commitment of capital and IT staff costs. Use of BT's extensive core network will allow for a more rapid implementation and provide the flexibility to accommodate new stores as required.

Dixons is implementing the initial stages of an IT programme to enhance its customer service capabilities and to provide it with the increased operational efficiency necessary to succeed in the competitive environment of the 1990s. Dixons has been looking at ways to respond to customer needs and further reduce operational and stock costs.

Dixons chose BT's managed data network solution because it provides the fastest and most cost-effective way of meeting the group's wide area networking needs. BT's Global Network Services (GNS) will enable Dixons to transmit data rapidly to sales staff allowing them to deal quickly with customers' enquiries and speed up management decision making. BT's GNS will support communications between 850 Dixons' and Currys' stores (including over 100 Currys' superstores), local distribution centres, service centres and head office. Plans also include links to credit agencies and suppliers.

Rapid access to up-to-date information on products and product features is essential for Dixons' sales staff, allowing them to respond knowledgeably to customer enquiries at the point of sales. For large electrical items, sales staff will be able quickly to call up information on stock availability, to place customer orders, schedule delivery and installation. BT's GNS will also provide the means for stores to interface directly with credit providers for the rapid sanctioning of credit deals, and to connect each store with Dixons' Mastercare system, to speed up customer repair enquiries.

The contract is further evidence of BT's position as a market leader in managed data networking services. It results from BT's in-depth knowledge of the retail sector and the company's commitment to providing a highly tailored solution that meets the operational needs and business requirements of individual customers.

BT's GNS is a portfolio of managed and value-added data networking services which are provided over BT's Tymnet Global Network (TGN). The TGN is wholly owned, managed and operated by BT. GNS, a leader in the managed data network services market, is provided and supported by BT on an end-to-end basis in 20 countries, with connections to over 70 additional countries. Conforming to international standards, GNS offers customers a choice of access options, protocol support and pricing schemes, along with a single point of contact with BT for managed data networking services worldwide.

BT Launches EDI*Net in UK and Continental Europe

BT has commercially launched its electronic data interchange (EDI) service, EDI*Net, in the UK and continental Europe. EDI*Net allows businesses to exchange a range of standardised documents, such as purchase orders and invoices, between computers. Access is available via BT's Global Network Services (GNS).

By extending the service (which has been publicly available in the USA since 1985) to UK- and European-based companies, BT is moving towards a worldwide EDI service.

BT has trading links with most businesses in the UK. This has given the company a deep understanding of service requirements in every market sector which, together with its international network, puts BT in a strong position to offer a competitive EDI product.

EDI*Net provides a store-and-forward service which accepts all of the major EDI standards—UN/EDIFACT, UN/GTDI and ANSI X12. Access via BT GNS is achieved through asynchronous dial, X.25 and IBM 2780/3780 BSC.

The service is competitively priced, with a single charge band for the whole of Western Europe and no additional charges for transatlantic traffic. The tariff structure is simple; EDI*Net customers pay for usage only, with an optional pre-payment scheme available, designed for high-volume users. There are no registration or subscription charges. EDI*Net provides flexible billing allowing trading partners to agree the allocation of cost between themselves.

In order to use EDI*Net, computer hardware, a communications capability, EDI translation software from the range that BT has certified as suitable for connection, and an EDI*Net mailbox are required. Each customer accesses the mailbox via BT's GNS and can typically transmit their documents for the day during a single communications session. The EDI*Net service validates and automatically sorts these electronic documents before placing them in the recipients' mailboxes to await collection.

The benefits of the EDI*Net service, which are applicable to businesses in all industry sectors, quickly become apparent: standardised data can be transmitted swiftly and accurately thereby eliminating manual rekeying errors; transaction handling times are reduced to minutes, leading to quicker trading cycles; prompt delivery times allow stocks to be held at a realistic level which leads to improvements in cash flow and capital expenditure, and better standards of customer service; closer trading relationships result in an increase in business.

EDI and EDI*Net were featured in an article—Electronic Trading: The Development of Electronic Data Interchange Services for British Telecom by D. J. Brunnen—on page 235 of the January 1991 issue of the *Journal*.

BT Launches Mobile Fax

BT's extensive ranges of mobile communications equipment now includes the PF-1, a compact fax machine that is just as much at home on the cellular network as it is on the public switched telephone network (PSTN).

Used in the car, the PF-1 can be powered through the cigar lighter and linked via an interface to the carphone. By clipping on the lightweight battery pack, it can be taken out of the car and used anywhere that a transportable cellphone can be used; for example, on the train, in a hotel lobby or out on site. Where a modern PSTN socket is available, the PF-1 can be used in the same way as a conventional office machine. An optional mains adapter is available.

Featuring advanced CCITT error-correction protocol for reliable high-quality transmission and reception even in weak signal areas, BT's PF-1 links via the appropriate data interface to virtually any carphone or transportable. The cellphone's existing features such as autodial and redial can be utilised to save time, and, as the primary use of the machine is expected to be on the road, the PF-1 can be set to answer calls automatically.

As the new machine was developed for mobile use, portability has been a prime consideration in its design. It weighs just 2·5 kg, and with a footprint smaller than A4, is recognised as being the smallest and lightest fax machine in the world capable of transmitting full-size A4 paper.

This concern with size has not been at the expense of performance. The PF-1 is fully compatible with all Group 3 machines, it has a fine detail function for transmitting maps and drawings, and the rechargeable battery pack provides enough power to send or receive up to 30 A4 documents. Powered from the car battery, there is no limit at all. This versatile unit can also be used to take urgent photocopies.

PF-1 mobile fax machine

Many people already think of the car as an extension to the office, but previously have had to rely upon the spoken word to keep in touch with colleagues and customers. The arrival of the PF-1 will enable them to send and receive reports, documents and even drawings wherever they happen to be at the time.

New Integrated Answering Service from BT Paging

BT Paging has launched a new integrated answering service which allows customers to both receive and send spoken messages, and be alerted to new messages on their BT pagers.

The computer-operated messaging system is simple to operate and involves no elaborate capital equipment or expensive installation charges. The customer needs only a BT pager and an MF TouchTone® telephone, or any other telephone using an MF tone keypad.

To contact a Message Link user, callers simply dial a telephone number and leave a spoken message of up to 60 s. Message Link notifies the user that a message has been received by calling the user's pager. A reminder alert is sent to the user's pager should the message not be picked up within 30 minutes. To listen to their messages, users simply dial their dedicated telephone number and enter their personal identity code—if necessary by using the keypad provided.

Message Link is ideal for sole traders, small businesses operating without a secretary and medium-sized companies with field personnel, all of whom depend upon efficient communications with colleagues and customers.

Message Link incorporates automatic voice prompts which are built into the system to offer guidance at each stage, and is therefore easy to use for both callers and users. Outgoing announcements to callers can be customised by the user as an additional feature.

This new service was launched shortly after the introduction of Number Master Direct, BT's sophisticated new low-cost paging service which allows callers to send messages straight to a numeric pager without the need to call an operator.

BT Paging Introduces Sophisticated New Pager

Message Master XL, a new alphanumeric 'widescreen' pager, has been launched by BT Paging. Message Master XL has a new easy-to-read screen, and incorporates many new features providing real customer benefits.

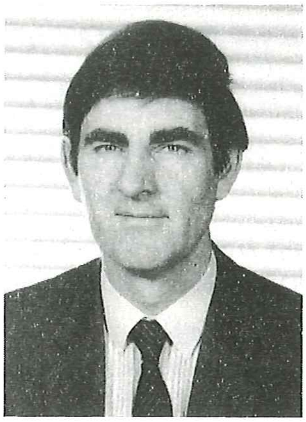
Message Master XL can display full text messages of up to 80 characters—more than twice the length of previous models. The alphanumeric message is constantly displayed on the large screen and can be read at a glance.

In addition to the widescreen, the Message Master XL provides a variety of beneficial features: the pager automatically stamps each message with the time and date as it is received; it can be programmed to turn itself on automatically and contains an integral alarm; a user-adjustable tone feature is incorporated into the pager and it also has an enlarged memory.

Message Master XL is one of the most advanced pagers available. Technologically, the Message Master XL is leading-edge, yet it remains user-friendly, easy to operate, and delivers real benefits to BT's customers. Paging is one of the most reliable and cost-effective means of mobile communications and Message Master XL allows users to keep in touch with full messages while on the move. They can control which messages are urgent and which need instant response.

Message Master XL pager

International Recognition for BT Director



Dr. Tom Rowbotham

Dr Tom Rowbotham, Director of Networks Technology at BT Laboratories at Martlesham Heath, has been elected Vice President for International Affairs of the US-based IEEE Communications Society. This is the first time that anyone from Britain has been elected to this post in the IEEE (Institute of Electrical and Electronic Engineers), which has 30 000 voting members worldwide. Dr Rowbotham will hold the post for two years from 1 January 1992.

His main task will be to chair the International Activities Committee of the Communications Society which is concerned with the IEEE's activities outside North America. He is particularly interested in helping the IEEE to become a more global organisation.

'As well as increasing IEEE membership in Eastern European countries such as Poland, Czechoslovakia, Romania and Hungary so that Western scientific information is available to them, I want to foster harmony and cooperation between national institutions, such as Britain's Institution of Electrical Engineers (IEE), and the IEEE,' he said.

Dr Rowbotham became Britain's IEEE representative four years ago as part of his commitment to BT's global strategy. 'We have to have a global culture within BT—and many of the people who think that way, certainly as far as technology is concerned, are here at BT Laboratories. Therefore I wanted to ensure an opening of minds towards the global aspects of communications technology and also to maximise the advantage of our prime position, as a leading laboratory, through exposure to other leading laboratories around the world,' he explained.

The IEEE is a learned society committed to exchange of information throughout the electrical and electronics research community around the world.

Forthcoming Conferences

Further details can be obtained from the conferences department of the organising body.

Institution of Electrical Engineers, Savoy Place, London WC2R 0BL. Telephone 071-240 1871.

Conferences:

Software Engineering for Telecommunication Systems and Services. 30 March–1 April 1992. Florence, Italy.

Information-Decision-Action Systems in Complex Organisations. 6–8 April 1992. Oxford.

Private Switching Systems and Networks. 23–25 June 1992. IEE, London.

Intelligent Systems Engineering. 19–21 August 1992. Heriot-Watt University, Edinburgh.

Electromagnetic Compatibility. 21–24 September 1992. Edinburgh.

Data Transmission. 23–25 September 1992. IEE, London.

Electrical Safety in the Work Place. 17–18 November. Luxembourg.

Developments in Power System Protection. 30 March–1 April 1993. University of York.

Power Electronics and Applications. 13–17 September 1993. Brighton.

Vacation Schools:

Systems Engineering. 29 March–3 April 1992. York.

Radiowave Propagation. 29 March–3 April. Chelmsford.

Network Technology. 12–15 April 1992. Swansea.

EMC Solutions by Design and Case Studies. 22–24 April 1992. Pontypridd.

Local Telecommunications. 12–15 July 1992, Birmingham.

Satellite Communication Systems. 26–31 July 1992. Guildford.

Optical Fibre Communications. 27–31 July 1992. Bangor.

Stepping into Management. 27–31 July 1992. Coventry.

Switching and Signalling in Telecommunication Networks. 6–11 September 1992. Birmingham.

Personal and Mobile Radio Systems. 6–11 September 1992. Swansea.

Safety Critical Systems. 13–16 September 1992. Coventry.

Digital Signal Processing: Principles, Devices and Applications. 27 September–2 October 1992. Leicester.

Seminars:

Seminar on Software Quality Improvement through Process Assessment. 5 March 1992. London.

Technical Seminar on the European Machinery Safety Directive. 25 March 1992. Bath.

Workshop on Configurable Distributed Systems. 25–27 March 1992. London.

Workshop on Neural Networks and Control and Systems:Principles and Applications. 1–2 April 1992. Reading.

Ninth UK Teletraffic Symposium. 8–10 April 1992. Guildford.

Seminar on Distributed MRP (Manufacturing Resource Planning—Material Requirements Planning). 4 June 1992. London.

Seminar on Total Quality Management—Delighting the Customer. June 1992. London.

Workshop on Specifying Requirements for Knowledge-Based Systems. 1 July 1992, London.

Notes and Comments

CONTRIBUTIONS TO THE JOURNAL

Contributions of articles to *British Telecommunications Engineering* are always welcome. Anyone who feels that he or she could contribute an article (either short or long) on a telecommunications engineering topic is invited to contact the Managing Editor at the address given below. The editors will always be pleased to give advice and try to arrange for help with the preparation of an article if needed.

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31st European Telecommunications Congress

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The 31st FITCE Congress, which will be held in Granada and Seville, Spain, from 27 September–2 October 1992, will be based on the theme:

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- overall impact on telecommunications operators.

In covering the above aspects, authors should consider the full range of telecommunications, including radio and television broadcasting, satellite services, etc.

If you are interested in submitting a presentation, please notify your intention as close as possible to 15 February 1992 to:

Paul Nichols, IBTE Office and Publications Manager, Post Point G012, 2–12 Gresham Street, London EC2V 7AG (Tel: 071–356 8022; Fax: 071–356 7942).

Please also send a summary of no more than 250 words before 29 February 1992 to the above address. The summary should give a clear indication of the theme and coverage of the proposed paper, and should contain details of your name, function or title, company, business address and telephone and fax number.

The FITCE Papers Selection Committee will advise authors during early-April 1992, after the final programme has been determined.

The full text of a selected paper, which is required by 15 June 1992, should be about 2000 words to allow for a 20 minute presentation and 10 minutes for questions and debate.

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